FRUIT FLIES AND THEIR CONTROL

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NEW DELHI

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PUBLISHED BY

INDIAN COUNCIL OF AGRICULTURAL RESEARCH
NEW DELHI

First Published, March, 1960

Chief Editor : PREM NATH

Price Rs.10

Printed by Norman A. Ellis, Baptist Mission Press, 41a Lower Circular Road, Calcutta 16.

PREFACE

The importance of fruits and vegetables in human dietary needs no emphasis. Besides making delicious dishes, they are the real source of energy in human body. Fruit consumption in our country as judged from the *per capita* consumption in other countries is too small, firstly because the land under fruit and vegetable cultivation is not enough to meet the demands of the people and secondly, a large proportion of the yield is destroyed by pests.

This monograph deals with fruit flies belonging to the family Tephritidae. Although, it has not been possible to exactly assess the loss caused by these flies to the cultivators by way of damage to the fruits, it can safely be said that it is enormous and if this menace is not controlled it may cause incalculable loss to fruit and vegetable farming and fruit preserving industry.

A lot of research work on the pests of fruits and vegetables has been done and various ways for controlling the population of the pest have been devised. In dealing with this subject in this monograph, control methods have been given greater importance, since a piece of research, however valuable it may be, will be of little value if it does not result in a substantial benefit to the cultivator and the industry. The control of these flies has been found extremely difficult as they breed in the pulp and the larvae live in fruits where no insecticide application in the form of dust or spray can reach them. The only course left for the entomologist is to tackle the adult fly. The various methods described in this monograph to control the fly are sure to go a long way in arresting the pest population which multiplies in geometrical progression, and the survival in each generation of even two to three females above the number necessary to maintain the population at an even level is likely to produce, in a relatively short time, disastrous results.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. B. P. Pal, Director, Indian Agricultural Research Institute, New Delhi, for providing all facilities for work, to N. E. Flitters, Entomologist, United States Department of Agriculture, Entomology Research Division, Brownsville, Texas, and to Dr. Elmo Hardy, Entomologist, College of Agriculture, Hawaii, for going through the manuscript and making valuable suggestions.

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CHAPTER I

FRUIT FLIES OF CULTIVATED CROPS

DIPTERA: TEPHRITIDAE

The fruit flies of the family Tephritidae are well-known pests of fruits throughout the world. Their attack on fruit not only reduces the yield but also affects the quality of the fruits as a result of which the commercial value of the crop is reduced and the fruit growing industry is rendered unprofitable. The Mediterranean fruit fly *Ceratitis capitata* Wiedemann, the most notorious of them all, causes serious damage to fruits, not only in the Mediterranean Coast but also in Australia, South Africa, Spain, Hawaii, Costa Rica and several other countries. Fortunately, this fly has not gained entry into our country so far. The Queensland fruit fly, *Dacus* (*Strumeta*) *tryoni* (Froggatt), is a common pest of Australian orchards. The Oriental (or mango) fruit fly, *Dacus* (*Strumeta*) *dorsalis* Hendel, is one of the most widespread and destructive species. It occurs in India, all the countries of southern and South-East Asia and most of the South-West Pacific Islands, like Formosa, Ryukyu and Hawaii. It attacks almost all types of fruits. The apple maggot, *Rhagoletis pomonella* Walsh., the cherry fruit flies, *R. cingulata* Loew and *R. fausta* O.S., the walnut husk fly, *R. completa* Cresson, are serious pests in North America and several species of the genus *Anastrepha* Schiner are important in South and Central America. The Japanese orange fruit fly, *Dacus* (*Tetradacus*) *tsuneonis* Miyake, occasionally causes damage to oranges (up to 40 or 50 per cent). The olive fruit fly, *Dacus* (*Daculus*) *oleae* Rossi, is a pest of olive orchards in Italy and France; and the last but not the least the melon fly, *Dacus* (*Strumeta*) *cucurbitae* Coquillett, is a serious pest of vegetables in China, Japan, Burma, Ceylon, Hawaii, Kenya, Africa and India.

The damage and loss caused by the Mediterranean fruit fly is very severe and the pest has been recorded from over 120 host plants. This not only points to the extreme adaptability of the pest but also to the seriousness of the problem of control of this pest. Fullaway (1949) states that the list of host plants of the Oriental fruit fly,

Dacus dorsalis Hendel, in Hawaii far surpasses that of the Mediterranean fruit fly. The damage caused by fruit flies in India, both to vegetables and fruits, is really enormous. The principal species are the Ethiopian fruit fly, *Dacus* (*Didacus*) *ciliatus* Loew, the melon fly, *D. cucurbitae* Coquillett, the Oriental or mango fruit fly, *D. dorsalis* Hendel, the peach fruit fly, *D.* (*Strumeta*) *zonatus* (Saunders), the guava fruit fly[1], *D.* (*Gymnodacus*) *diversus* Coquillett, and the ber[2] fruit fly, *Carpomyia vesuviana* Costa. It has been observed that the host plant index of each species is also increasing and this adds to the complexity of the problem.

There are some Tephritidae which attack well-known field crops, viz., *Acanthiophilus helianthii* Rossi, and cause serious damage to safflower.

ASSESSMENT OF DAMAGE

It is difficult to correctly appraise the extent of the damage or assess the loss caused to the cultivator by the pests except in very general terms. This is not only due to the complexity of the problem but also to the interplay of other factors like the variety of the fruits grown, the resistance offered by these varieties to the attack by flies, the influence of environmental factors particularly climatological conditions and lastly the fluctuating market value. All these make it difficult to assess the damage caused and the average loss to the cultivator from year to year. Yet, information on this aspect of the problem is necessary, if only to prove the effectiveness of the control methods adopted. In any case, it can be safely stated that the damage caused by these flies to fruits as well as vegetables in the Indian Union is very large. Almost every grower must have experienced that it is almost impossible to get vegetables like the bitter gourd (*Momordica charantia*), *Luffa* species (*Luffa cylindrica* and *L. acutangula*) and the fruits like mango, guava, loquat, pear, etc., free from infestation by various fruit flies.

It must, however, be emphasized that the damage by fruit flies is not limited to fruits and vegetables. It can, however, be stated without any fear of contradiction that the horticultural industry suffers most from the depredations of these pests.

[1] The authors have named this fly as guava fruit fly, because of their large numbers seen in guava and loquat orchards during the winter months (December to February).

[2] An Indian drupe, the poor man's fruit.

IMPORTANT SPECIES OF FRUIT FLIES AND THEIR NOMENCLATURE

This monograph gives a brief review of the bionomics and biology of all the well-known Indian species of fruit flies and the methods of their control. The control aspect of the problem has been given greater importance as any research will be of little value unless it leads to the control or eradication of the pest concerned. Batra has made detailed observations on some of these species and also experimented with a large number of attractants and found the 'clensel'[1] most promising. The detailed methods of its dilution and the time of its exposure linked with the seasonal history of the fruit fly in the field are given in detail in this monograph. The object of this control method is to reduce the fly population in the fields. Moreover, the chemical attractant plays a useful rôle in estimating the population levels. This is of considerable significance for if we bring about an initial reduction in the population, the ultimate population will be very much reduced as insects multiply in geometrical progression. As Thompson (1930) observes, "Since organisms increase in geometrical progression, the survival in each generation of even two or three females above the number necessary to maintain the population at an even level, may produce, in a relatively short time, disastrous results. For example, one female of a species with a three-fold increase per generation will have in the twentieth generation almost 8,000,000 descendants. This explains the phenomenal spread and catastrophic power of certain introduced insects."

The following Table shows the important species of fruit flies which are distributed not only in India but other countries of the Oriental region as well:

1. *Dacus* (*Strumeta*) *dorsalis* Hendel
2. *Dacus* (*Strumeta*) *zonatus* (Saunders)
3. *Dacus* (*Strumeta*) *cucurbitae* Coquillett
4. *Dacus* (*Strumeta*) *correctus* Bezzi
5. *Dacus* (*Strumeta*) *latifrons* (Hendel)
6. *Dacus* (*Strumeta*) *nubilis* Bezzi
7. *Dacus* (*Strumeta*) *nigrotibialis* (Perkins)
8. *Dacus* (*Gymnodacus*) *diversus* Coquillett
9. *Dacus* (*Zeugodacus*) *hageni* deMeijere

[1] 'Clensel' is a proprietary product manufactured by John Paterson & Co., Howrah.

10. *Dacus* (*Zeugodacus*) *duplicatus* Bezzi
11. *Dacus* (*Zeugodacus*) *maculipennis* Doleschall
12. *Dacus* (*Didacus*) *ciliatus* Loew
13. *Dacus* (*Daculus*) *oleae* var. *asiatica* Silvestri
14. *Myiopardalis pardalina* Bigot
15. *Carpomyia vesuviana* Costa
16. *Acanthiophilus helianthi* Rossi

GENERIC NOMENCLATURE OF THE SUBFAMILY DACINAE

Bezzi (1913) treated most of the Dacinae listed in Chapter I under the genus *Bactrocera* with *Strumeta* and *Dasyneura* as synonyms. He also tentatively proposed the name *Chaetodacus* for those *Dacus sens. lat.* with unbanded wings but did not list species under this combination till his later paper (1916) was published. Perkins (1937) reviewed the genera of Dacinae and restricted the genus *Dacus sens. str.* to Africa. He arranged the economically important species of India, of this subfamily, under the 'genera' *Strumeta* Walker, *Zeugodacus* Hendel, *Didacus* Collart and *Asiadacus* Perkins. Munro (1939) preferred to retain the genus *Dacus sens. lat.* with the above groups as subgenera. Hardy (1951, 1954*a*, 1954*b* and 1955) has pointed out that the splitting of *Dacus sens. lat.* into so-called genera based only upon secondary sexual characters or single chaetotaxic characters is not a sound practice and he follows Munro in treating these as subgenera. Hardy (1955) has described up-to-date taxonomy of this group in his paper '*Reclassification of the Dacini*'.

CHAPTER II

BIONOMICS AND BIOLOGY

DACUS (STRUMETA) DORSALIS HENDEL

This species has been treated in most of the Indian literature under the name *Dacus ferrugineus* (Fabricius). Dr. D. E. Hardy of the University of Hawaii has, however, pointed out that the name *ferrugineus* is pre-occupied and is not available for this species. He has discussed this in detail in his paper (in press), *Taxonomy and Distribution of the Oriental Fruit Fly and Related Species.* The so-called varieties of this species in India (*mangiferae* Cotes, *incisus* Bezzi, *nec* Walker and *varsicolor* Bezzi) are treated as outright synonyms by Hardy; these were based upon general specimens and are not good varieties.

Distribution. This fly is popularly known as the mango fruit fly in India and the Oriental fruit fly elsewhere. It is widely distributed throughout India. This species is rapidly assuming the status of a major pest in the countries where it is present. Outside India, it has been recorded from Pakistan, Ceylon, Burma, Siam, Java, Malaya, Mauritius, Philippines, East Indies, Amboina, China, Formosa, Taiwan, Bonin Islands, Australia and Hawaii. In Hawaii, the fly was first recorded in 1946, though it is presumed that the species existed in the island perhaps a year earlier. It has lately assumed a serious form and has displaced the Mediterranean fruit fly which was so far the major species.

Food Plants. The fly attacks a wide variety of fruits and vegetables such as mango (*Mangifera indica*), guava (*Psidium guajava*), loquat (*Eriobotrya japonica*), apricot (*Prunus armeniaca*), plum (*Prunus domestica*), peach (*Prunus persica*), pear (*Pyrus communis*), wild fig (*Ficus* sp.), cultivated fig (*Ficus carica*), *Ficus mysorensis*, apple (*Pyrus malus*), quince (*Pyrus cydonia*), persimmon (*Diospyros* sp.), banana (*Musa* sp.), *alu bukhara* (*Prunus* sp.), *shalil* (*Prunus* sp.), pomegranate (*Punica granatum*), *chiku* (*Achras sapota*), jujube (*Zizyphus jujuba*), sweet lime (*Citrus limetta*), Malta orange (*Citrus sinensis*), *santra* (*Citrus reticulata*), pomelo (*Citrus grandis*), sour orange (*Citrus*

aurantium), *galgal* (*Citrus medica*), orange (*Citrus nobilis*), chillies (*Capsicum frutescens*), American chillies (*Capsicum* sp.), Jack fruit (*Artocarpus integrifolia*), brinjal (*Solanum melongena*), *Solanum verbascifolium*, *Solanum aurantium*, *S. robuslifolium*, *S. auriculatum*, *Cephalandra indica*, *Careya arborea*, ripe *bael* (*Aegle marmelos*), sandalwood berries and Honde fruits. In Pakistan, Burma and Ceylon the species also attacks carambola, *Rambutan sapodila*, papaya (*Carica papaya*), *Eugenia aquea*, *Diospyros packmanni*, *Sandricum indicum*, avocado, bread fruit (*Artocarpus communis*), coffee berries (*Coffea arabica* and *C. robusta*), passion fruit (*Passiflora* sp.), *Terminalia catapa* and the star apple (*Chrysophyllum cainito*), Spanish pepper, cucurbit fruits, *Solanum torvum*, cherries, nectarine, blackberry, cape gooseberry, grapes, mulberry, *Notalaea longifolia* and *Carissa ovata*.

It may be pointed out that the indices of infestation vary in these particular fruits and is influenced by the maturity of same. Some of the hosts listed are ovipositional sites only. Pre-imaginal development seldom is successful in passion fruit, etc.

In Hawaiian Islands it has been recorded from over 250 host fruits. In addition to those recorded in other countries some of them are listed below.

Strawberry guava (*Psidium littorale*), *Psidium* sp., lemon (*Citrus limon*), Chinese orange (*Fortunella japonica* var. *hazara*), mock orange (*Murraya exotica*), passion fruits (*Passiflora edulis* var. *flavicarpa*, *P. foetida*, *P. laurifolia*, *P. subpeltata*), plum (*Prunus* sp.), Natal plum (*Carissa grandiflora*), Damson plum (*Chrysophyllum olivoforme*), coco-plum (*Chrysobalanus icaco*), governor's plum (*Flacourtia indica*), Madagascar plum (*Noronhia emarginata*), Methley plum (*Prunus salicina*, *P. cerasifera*), peach (*Prunus vulgaris*), mountain apple (*Jambos* (*Eugenia*) *malaccensis*), rose apple (*Eugenia jambos*, *E. uniflora*), *Spondias dulcis*, *Mammea americana*, sand pear (*Pyrus serotina*), avocado (*Persea americana*), Ceylon gooseberry (*Dovyalis hebecarpa*), olive (*Olea europaea*), dates (Arabian seedling), persimmon (*Diospyros kaki*), *Diospyros discolor*, litchi (*Litchi chinensis*), tomato (*Lycopersicum esculentum* very rarely), Liberian coffee (*Coffea liberica*), *Solanum muricatum*, cactus (*Opuntia megacantha*), sour sop (*Anona muricata*), bullock heart (*Anona reticulata*), *Cananga odorata*, *Artabotrys uncinatus*, cainistel (*Luccuma nervosa*), sea grape (*Coccoloba uvifera*), carambola (*Averrhoa carambola*), *Bumelia rotundifolia*, *Capsicum frutescens abbreviatum*,

Bell peppers (*Capsicum frutescens grossum*), longan (*Euphoria longan*), *Garcinia xanthochymus*, elengi (*Mimusops elengi*), cotton (*Gossypium barbadense*), *Inga laurina*, *Manilkara emarginata*, Allspice [*Pimenta dioica* (*officinalis*)], bay [*Pimenta racemosa* (*acris*)], Opiuma [*Pithecellobium* (*Pithecolobium*) *dulce*], *Polyalthia longifolia*, *Yucca aloifolia*, ripe bananas [*Musa nana* (*cavendishii*)], banana (*Musa sapientum*), Chinese banyan (*Ficus retusa*), Port Jackson fig (*Ficus rubiginosa*), Moreton Bay fig (*Ficus macrophylla*), *Zizyphus mauritiana*, *Ochrosia elliptica*, macadamia nuts (*Macadamia ternifolia*), *Calophyllum inophyllum*. Tender coconut, *Cordia sebestena*, latania palm (*Latania loddigesi*), *Scaevola frutescens sericea*, watermelon, vanda orchid (blossom and buds), English walnuts, etc.

It may be stated that this list contains fruits that were infested sometimes to a lesser degree than would be acceptable on the true merits of a host and compilation of the hosts was made at the peak of the fruit fly population in Hawaii.

In the case of such hard fruits as walnuts, coconut and macadamia nuts the female oviposits into the mesocarp of the fruit when they are tender. But the development and growth of fibrous tissue in these fruits retards the growth of developing larvae and causes their death.

In captivity, the fly has also been reared on bitter gourd (*Momordica charantia*). Efforts to rear this fly from the sterile fruits of *Ficus heterophylla* have been unsuccessful even though attempted oviposition in them by the female has been observed in the field.

Nature and Extent of Damage. Perhaps no other pest of orchard or vegetable crops causes damage so varied and so severe as this species of fruit fly. Indeed the external damage varies from host to host although the pattern of the damage inside the pulp is more or less similar. As the orchard grower and the scientists will be interested in the external symptoms of the damage caused by this fly each fruit has been dealt with separately and the damage caused described in detail. Generally speaking, the adult female lays eggs just below the epidermis or sometimes a little deeper in the pulp. The insertion of the ovipositor causes wounds on the fruit or vegetable in the form of punctures, which appear like dark spots on the fruits. In freshly punctured specimens, the fluid that exudes collects in the form of a droplet which later dries up and appears like brown

resinous deposit. In other fruits such as pineapple, wild yeasts collect at the point of incision and fermentation of the fruit results. As soon as the eggs hatch the maggots bore their way to the interior, destroy and convert the pulp into a bad smelling, discoloured semiliquid mass totally unfit for human consumption or even for cattle. The fruit develops a brown rotten patch and falls on the ground. The nature of damage caused to different fruits is briefly described below.

GUAVA: The guava, which is widely grown in plains throughout India, is a very popular fruit famous for its delicious flavour. The attack by the fly is observed in orchards in the beginning of July and continues uninterruptedly throughout the season where the climatic conditions are equable as in the subtropical south, or till the extreme cold sets in about the middle of November in the north when the fly hibernates in the pupal stage. The attacked fruit has on its surface a small round depressed area in which there is a clear dark greenish puncture about the size of the sharp end of a pin. The damage to guavas is generally at its peak during mid-July to September when the hard fruits as well as those that are ripe are heavily infested. Over 12 punctures have been counted on one medium sized fruit. The fruit falls only when it is overripe. A fairly hard fruit seldom falls during the winter. It generally dries up on the tree. The harvest of the summer crop of guava is generally complete by the middle of October. The winter crop goes on gradually ripening and provides an excellent medium in which the flies continue to breed. Often the fly punctures different parts of the fruit but does not lay eggs at all, or lays eggs only in a few of the punctures where it finds the pulp soft. Those punctures where eggs are not laid are known as pseudo-punctures and though the fruit may be quite healthy and palatable, the commercial value of the crop is often reduced because of the discoloration. The larvae, when full-fed, bore their way out of the fruit, sometimes through as many as four exits and fall to the ground where they pupate. In the case of small hard fruits, the larvae develop rather slowly as the fruit ripens. Later the rind becomes dry and hard. In such exceptional cases, the larvae pupate inside the fruit but in doing so most of them perish. Occasionally, however, some flies are able to emerge from such fruits when through some accident the hard fruit splits or organisms of decay cause decomposition of the fruit.

LOQUAT: This fruit is grown in the Punjab, Delhi and western Uttar Pradesh. The fruit begins to ripen in March-April and it is almost immediately attacked by the fly. The puncture made by the fly is dark and is clearly visible against the deep yellowish background. The juice starts trickling just after the attack. The fruit does not fall but remains *in situ* till it has completely dried up. The season for the fruit is over by the middle of May, but the fly continues to breed in the undersized and overripe loquat which remain unpicked on the tree till the end of May.

APRICOT: This widely popular fruit is grown in small areas in north-western India. The area is bound to increase as years pass. Since partition, we have depended for apricots, to a great extent, on imports and hence it is in our interest that the damage caused by this fly is reduced to minimum. The attack by the fly appears on the fruit in the form of a dark coloured puncture which is quite conspicuous against the yellow or light greenish white background of the fruit. The maggots feed in the pulp of the fruit, as a result of which the pulp begins to rot. The damage is often heavy. The fruit drops on the ground. The period of attack by the fly lasts from May in the plains up to the last week of July in the hills.

PLUM: The cultivation of plum is confined to areas where apricot and other deciduous fruits grow (2,000 to 6,000 ft. elevation). The plum is attacked only if the fly is unable to find any other fruit like loquat, apricot, peach, etc., in the field. Observations have shown that plum is very little liked by this species and the damage caused to it by the fly is negligible. The fly begins to lay eggs from the second week of May up to the end of June in the plains and up to July in the hills. The juicy as well as the pulpy varieties are attacked. In juicy fruits, the fluid comes out of the punctures and it is often difficult to locate the young maggots. Many perish in the fluid and only a few reach the maturity. In pulpy varieties, a brown patch of hardened tissue is visible. The affected fruits eventually drop down.

PEACH: The peach is a well-known deciduous fruit famous for its rating excellence and canning qualities. The fruit fly puncture is not so very conspicuous in this fruit due to the soft hairy pubescence on the skin. The fruit is attacked when it is immature. If the freshly attacked fruit is slightly pressed a dirty brown fluid oozes out from the point of puncture. With the growth of maggots inside,

a brown soft rotten patch becomes visible on the surface of the fruit. This is soon followed by the dropping of the peach. The damage is often extensive as well as intensive. Early ripening varieties of peach are attacked in June-July. Late ripening varieties are attacked in August.

Pear: The pear is mostly grown in the hills but some of the harder varieties are grown in the plains also. The fly attacks the fruit in July when it is very hard and raw, and the attack is continued right up to the month of October, only in places where guava fruit does not grow; otherwise the fly migrates to guava orchards where the fruit is attacked as soon as it begins to ripen. As in the previous cases a clear dark puncture is visible on the surface of the fruit. As the maggots feed toward the core, the fruit begins to rot. A shiny drop of fluid oozes out when the fly punctures an unripe fruit, and as the maggot begins feeding inside, a gummy brown fluid is observed oozing out from the point of puncture. The fruit fall is gradual in the case of underripe fruit, but it quickens in the case of ripened fruit.

Wild Fig: The wild fig is attacked in the month of June only in areas where fruits dealt with earlier are not grown. The fruit of wild fig is attacked by the fly when it is ripe. As the maggots feed inside, the fruit rots. The fully grown maggots escape in the soil for pupation and the fruit dries up in the tree.

Cultivated Figs: Cultivated varieties of figs are grown in small areas in some parts of India like the Punjab, Uttar Pradesh, Deccan, etc. They are attacked by the fly when the fruit is fully ripe. The latex of the underripe fruit is not conducive to the growth and development of the larvae. When the fruit is underripe the eggs are inserted through the calyx. In the calyx there is less latex and the maggots bore directly into the pulpy mass of the fruit. This is an ingenious method of getting over the injurious effect of the latex of the unripe fruit. Dark brown gummy exudate oozes out of the puncture caused by the ovipositor of the fly. The figs are attacked from the second week of July to the end of November.

Mango: The mango is rightly called the king of fruits in India and is the only fruit that the poor as well as the rich equally enjoy. The dark puncture caused by the oviposition of the fly in mango is not conspicuous as its colour blends with the dark green colour of the fruit. It is, however, visible on some pale brown varieties which

are attacked first when they begin to ripen. After the maggots have fed on the pulp of the fruit for a few days, a brown rotten patch appears on the fruit surface. The mesocarp also becomes dirty brown in the region the maggots feed. The fruit eventually falls and the maggots emerge to pupate in the soil. The fruit is attacked from June to August. The damage caused is oftentimes heavy.

APPLE: The apple is grown in the hilly regions especially in North India. Generally, this fruit is not attacked by the fly, but during the years of severe outbreak even this is not spared. A dark puncture appears on the fruit which, later on, develops into a brown hard patch as the maggots feed and grow in size. It is attacked in August-September.

PERSIMMON: In this fruit the dark puncture made by the fly is very prominent against the reddish background of the fruit. Rot sets in and the fluid oozes out of the ripe fruit as the maggots feed inside. The fruit does not fall unless fully decayed. It is attacked in the month of October.

BANANA: The banana when underripe is seldom attacked. As the banana bunch is cut off when it is still unripe and is ripened under artificial conditions, the attack by the fly is not generally observed in the gardens. When the banana begins to ripen on the bush the flies attack. When the maggots begin to develop inside the skin, the banana turns black and forms the nucleus of the initial population which, unless promptly checked, will eventually increase to a very large number. This fruit is attacked by flies during the months of August-September.

PLUM (*Alu Bukhara*): This variety of plum is grown extensively both in the hills as well as in the plains. The fly sometimes attacks this fruit in September. No extensive damage has been observed. The affected fruits decay quickly and cannot stand shipment. So we do not come across damaged fruits in the market as they are all removed before sale.

POMEGRANATE: The pomegranate is grown throughout India. The rind is too thick and strong for the fly to thrust its ovipositor in, but eggs are deposited through the natural cracks which are very common in this fruit in the months of September and October. The fruit is spoiled and emits a nasty smell after infestation.

Quince: The quince is grown in the hills. It is a hard fruit and, therefore, is attacked only when it has developed a pale green colour which is the symptom of ripening in October. The dark puncture is clearly visible then. The maggots riddle the core and render the pulp unfit for consumption. As soon as the maggots feed and develop, the fruit begins to fall to the ground. This fruit is attacked by the fly only when no other fruit, acceptable to it, is available.

Citrus Fruits: Many species of citrus are attacked by the fly, namely sweet lime (*Citrus limetta*), Malta orange (*Citrus sinensis*), *santra* (*Citrus reticulata*), pomelo (*Citrus grandis*), sour orange (*Citrus aurantium*) and *galgal* (*Citrus medica*). The sweet lime is attacked when still green, which causes it to turn orange prematurely and thus the dark puncture is easily visible against the orange background. Except in sweet lime and Malta orange, the maggots in the rest of the fruits perish soon after hatching in fruits with thick rind. It is only when the eggs have been laid near the pulp that the maggots survive. In sweet lime and sometimes in Malta orange the eggs are laid directly in the pulp. The fruit begins to fall slowly after the eggs have been laid. The maggots that hatch out from these eggs eventually develop into adult flies. Circular and depressed almond brown patch is visible on the surface of the fruit as a symptom of attack when the maggots feed inside. Citrus fruits are attacked from October to December. It is on record that in Formosa citrus is their favoured host.

Bionomics. Janjua (1948) and Shah, Batra and Renjhen (1948) have published the bionomics and biology of this pest under the name *D. ferrugineus* Fab.

The fly has been observed to be active in the field almost throughout the year where the weather is equable. In places where there is a clear-cut winter it enters into hibernation in the pupal stage from the first week of November up to about the beginning of April in the plains and June in the hills. If, however, the season is early or late, the hibernation may end even in March or May as the case may be. The flies are observed flying about in orchards and kitchen gardens where the fruits are grown. They are most active at temperatures ranging between 77–86° F. and become inactive below 68 °F. In the beginning of the summer the damage caused by the fly is not

severe but soon several broods complete their life-cycle in quick succession, the population increases and the intensity of attack as well as the damage increase proportionately. There are a large number of deciduous fruits that grow and ripen throughout the summer for the flies to feed and breed upon. In March, guava abounds, while the period between April and May is passed in loquat, apricot and plum. June is passed in peach, wild fig and brinjal. June is a month of fruit scarcity in many places. In Delhi it has been observed that about this time the fly resorts to breeding in brinjal, a fruit in which it carries over with difficulty. Owing to drought, shortage and unsuitability of the host material there has been observed a drop in the population of the pest in its immature stages. The adults, however, successfully survive and tide over this period by feeding on the honey-dew of the aphids infesting brinjal. July is passed in mango, peach and pear. The peak of attack is reached from August to October when the shortest duration of its life-cycle from egg to adult is about a fortnight, which is, generally, four to six times this period in colder months. During this period the flies mostly breed in guava but may be found in pear, fig, quince, apple, persimmon, citrus and ripe banana also. In winter, i.e. from November onward, the host supply runs short and, therefore, the damage to individual fruits is rather severe. The number of maggots in a single fruit is then the maximum. In November when the seasonal conditions do not force the flies to hibernate as pupae they breed in late pear, quince, winter guava and citrus fruits that may be growing in the smaller areas. Guava and citrus are the main hosts in the winter months. The broods of flies generally overlap. The adults are long-lived and may live for four months in the field. In Hawaii, their longevity is more than one year at higher elevations. During this period they feed on exudations from ripe fruits and honey-dew of insects. They are observed hovering about the orchards for a fortnight to three weeks after the fruits have ripened and have been picked. They also do this in presence of fruits. As the summer passes into winter, the flies gather in numbers under the leaves in the evening and rest there during night. In the morning, they may continue to rest even up to 12 a.m. until the temperature warms up. Slightest disturbance is enough to warn them of the approaching danger and they quickly fly away if it is sunny and warm. The flies are active and agile but can

be easily collected by hand in a tube when in the act of oviposition on the fruit or resting on under-surface of the leaf. Infested fruits normally show one puncture but when the intensity of attack is high and the number of fruits left on the tree is small, one fruit may contain as many as a dozen punctures. In the act of oviposition, it has been observed that the flies exercise judgement in laying a few eggs in fruits like loquat which have less pulp than mango, etc.; where the pulp is hard, the flies merely make pseudopunctures like those often found in the guava. In Hawaii, it has been observed that the percentage of successful emergence differs in different fruits and it has also been observed that whereas in opuntia it is only 37 per cent, in papaya it is as high as 99 per cent. In beach naupauka (*Scaevola frutescens sericea*), however, the maggots are seldom able to develop and form puparia and the percentage of emergence has been observed to be as low as 1 per cent. Due to pressure of population the flies oviposit and develop in such unnatural hosts as cotton bolls. It has also been observed that the fruits of common ornamental date-palm serve as an alternate host. The population goes down from December onwards and thereafter the pest is observed only in its immature stages till the beginning of summer. The maggots are able to mature in strongly acidic fruits but prefer those with 3·5 *p*H. There is heavy mortality, viz. up to 60 per cent or even more, in the pupal stage during the winter months. With the beginning of spring, however, the flies are able to build up their population strength and become a menace again.

Life History. Mating between the adult flies takes place at about dusk and lasts for about an hour or more. According to Janjua (1948) the pre-oviposition period is two to five days but it may range from ten to fifteen days or longer in varying conditions of climate and diet. In Hawaii this period ranged from eight to sixteen days when the flies were fed with fortified enzymatic yeast diet but it may be extended to 30 days in the absence of suitable diet. The female fly lays eggs in small clusters just underneath the skin of the fruit, 1–4 mm. deep in the rind. Tactile bristles on the ovipositor assist the fly to discriminate between hard and soft surfaces for oviposition. As soon as a suitable spot on the fruit is located it bends its abdomen at a right angle to the long axis of the body and moves the distal needle-like structure of the ovipositor and the proximal tube deeper

and deeper until it disappears entirely and the eggs are then deposited. After the act of oviposition the ovipositor is withdrawn leaving a puncture behind (Plate I, fig. 1). The complete act of oviposition takes sometimes about five minutes. Each cluster may contain between 2 to 15 eggs (one egg is shown: Plate I, fig. 2) depending upon the texture and quantity of the pulp available in each kind of fruit. On an average about 50 eggs are laid, but under favourable conditions a single fly may lay as many as 150–200 eggs, in a period of about one month. In Formosa, the maximum number of eggs laid by a single fly has been observed to be sometimes as high as 1,000. The incubation period of the eggs is two to three days during March and April and 24–36 hours throughout the summer months. It may be prolonged up to ten days in winter. The young larva is white, translucent and measures 1·5 mm. × 0·3 mm. The full-grown larva is 8 to 9 mm. long and 1·5 mm. broad across the posterior end (Plate I, fig. 3). The larva is yellowish in colour due to the accumulation of reserve material in the form of fats, etc., and is hence opaque. The head of the cephalic segment is pointed anteriorly and trapezoidal in outline. It bears on its dorsal surface two antennal protuberances and the maxillary palps. Red stigmata which constitute the posterior spiracles are very conspicuous and are present on the last abdominal segment. A pair of anterior spiracles is, however, borne by the first thoracic segment. Normally a fruit may contain a dozen maggots but in the case of shortage of host fruit, one fruit may have ten times this number. In Hawaii this number varies from 30 in many fruits to as many as 500 in papaya fruit and on many occasions over 1,000 pupae have been recovered from papaya. The larval period lasts from 6 to 29 days depending upon the period of the year. The shortest period of six days was worked out during September and the longest period in the last week of December and the first three weeks of January. In April it was 12 days. The fully developed larva (only third instar) has a habit of jumping a short distance (three to four inches) to find a suitable place for pupation. The pre-pupal period ranges from 18 hours in summer to two days in winter. The pupa (Plate I, fig. 4) is cylindrical in shape and is 4-5 mm. long and 2 mm. broad. The colour varies from dull deep reddish yellow to ochraceous. Under-fed pupae are straw-coloured and measure on an average 4·25 mm. × 1·25 mm. The internal transformation in such pupae hardly takes place in the normal

way and even if the fly emerges it is small and weak and succumbs to the slightest adversity in its biotic struggle. There are 11 distinct segments, the last segment being a little more prominent. The anterior spiracles are much darker but similar to those of the larva. The posterior spiracles are situated below the mid-horizontal line and are yellowish in colour. Each spiracle has three small but relatively broad openings. The pupal period lasts from 6 to 44 days. Pupation normally takes place three to seven inches below the soil surface. Pupae kept at a constant temperature of 33° C. and varying humidities of 20, 45, 65 and 85 per cent showed that no development took place where the humidity was lowest. At a humidity of 85 per cent the flies had formed and some of them broke open the pupal case but the adults died, before they could extricate themselves. Exposure of the adult flies to the above constant temperature and humidities revealed that the adults died within 24 hours in all the humidities excepting 85 per cent in which they lived for three days. Thus it is evident that low humidity and high temperature of 33° C. are fatal to the pupae and adults. The well-developed adult is stout and a little bigger than the ordinary house fly and measures 14 mm. across the wings and 7 mm. in maximum length. The male fly (Plate I, fig. 6) is slightly smaller in size than the female. The female (Plate I, fig. 5) has a tapering abdomen which ends in a pointed ovipositor. The fly is brown or dark brown in general colour, with hyaline wings and yellow legs. The thorax is ferruginous and brownish black arranged in varying patterns.

DACUS (STRUMETA) ZONATUS (SAUNDERS)

The species *Dacus zonatus* (Saunders) is next to *D. dorsalis* Hendel in respect of the severity of damage that it causes in the orchards. It has been more often recovered from the peach fruit and, therefore, it is rightly called the peach fruit fly.

Distribution. It has a wide distribution in the Indian Union. It has been recorded from Pusa and Ranchi (Bihar), Coimbatore and Tranquebar (Madras), Santikopa (N. Coorg), Amroha, Allahabad and Moradabad (Uttar Pradesh), Panchmarhi (Madhya Pradesh), Bangalore (Mysore), Poona and Nagpur (Bombay) and the Punjab. Outside India it has been recorded from West Punjab, North-West

Dacus dorsalis Hendel

1. Mango showing puncture caused at the time of oviposition 1*a* and the rotten patch developed afterwards 1*b*. 2. Egg (×24). 3. Full-fed maggot (×9). 4. Pupa (×9). 5. Female fly (×6). 6. Male fly (×6). 7. Braconid parasite (×6).

Dacus zonatus Saunders and *Dacus diversus* Coquillett

1. Female of *Dacus zonatus* (×9). 2. Male of *Dacus zonatus* (×9). 3. Damaged peach with the maggots *in situ* (natural size). 4. Female of *Dacus diversus* (×9). 5. Male of *Dacus diversus* (×9).

Frontier Province and Baluchistan (West Pakistan), Ceylon, Amboina and Egypt.

Food Plants. A variety of fruits are attacked by this species in India. Recorded cases are peach (*Prunus persica*), mango (*Mangifera indica*), fig (*Ficus carica*), guava (*Psidium guajava*), sapota (*Achras sapota*), *ber* (*Zizyphus jujuba*), citrus (*Citrus* sp.), *bael* (*Aegle marmelos*), bottle gourd (*Lagenaria vulgaris*), tomato (*Lycopersicon esculentum*), long melon (*Cucumis utilissimus*), *tori* (*Luffa* sp.), *Careya arborea*, brinjal (*Solanum melongena*), *Basolia latifolia* and custard apple (*Anona squamosa*). Pomegranate (*Punica granatum*), apple (*Pyrus malus*) and pear (*Pyrus communis*) have also been recorded as host plants in West Pakistan.

Nature and Extent of Damage. The light dark coloured puncture, the characteristic oozing of fluid, the rotting of the fruit (Plate II, fig. 3) and its eventual fall are the usual symptoms.

Bionomics. The adult flies (Plate II, fig. 1 and 2) remain active throughout the year except for a short period in winter from the beginning of January to the end of February. The pest overwinters mostly in the pupal stage. As the flies have been observed under bushes during the winter months, it is likely that this species also has a tendency to congregate under the leaves like *Dacus dorsalis* Hendel. This observation has to be confirmed by future workers. In spring the fly becomes active earlier and breeds in *ber* (*Zizyphus jujuba*) which is common then. Later on, it causes damage to loquat and peach fruits in May and June. In the latter month it also breeds in cucurbit vegetables which are then plentiful. Months of monsoon are passed in mango and gradually the damage is observed in guava, sapota, pomegranate, citrus and *bael*, etc., in the post-monsoon period. The pest is very active during the rainy months in summer when the population of the fly is at its peak. One interesting fact that has been made in the field is that this species which was found in large numbers and was bred from a variety of fruits is now becoming scarce when compared with its original population. *D. dorsalis* Hendel has now almost ousted it. This opens a vista for further research by future workers. A similar observation has been made in Queensland where *Dacus troyni* Froggatt has displaced the Mediterranean fruit fly (*Ceratitis capitata* Wiedemann) in the matter of intensity of its population. Similarly, it has been observed in Hawaii that the

Oriental fruit fly (*Dacus dorsalis* Hendel) has displaced the Mediterranean fruit fly to a great extent.

Life History. The life history of this species bears some resemblance to *D. dorsalis* already described in detail. Hussain (1929) observes that it is active throughout the year except for a short period from January to the middle of March. The pre-oviposition period is about 20 days and the female has been observed to lay about 137 eggs in her lifetime. The eggs are laid under the rind of the fruit in clusters of two to nine. The fully developed larva falls on the ground and pupates in the soil. Many points in the life history of this interesting species are yet unknown and the investigator will find a fascinating problem in the biology of this fly discovering why it is dwindling in numbers.

DACUS (STRUMETA) CUCURBITAE COQUILLETT

Dacus cucurbitae Coquillett is commonly known as the melon fly (Plate III, fig. 6 and 7). It attacks a large variety of cucurbits, other vegetables and occasionally fruits. Originally described from Hawaii, its native home is considered to be in the Oriental region, probably India or South-East Asia.

Distribution. The fly is distributed throughout Indian Union. Outside India it has been recorded from Nepal, Pakistan, Ceylon, Burma, Siam, Federated Malay States, Java, China, Formosa, Philippines, Hawaiian Islands, Australia and East Africa.

Food Plants. The fly has been reared in India in pumpkin (*Cucurbita maxima* and *C. moschata*), cucumber (*Cucumis sativus*), musk melon (*Cucumis melo*), snap melon (*Cucumis melo* var. *momordica*), long melon (*Cucumis utilissimus*), wild cucurbit (*Cucumis trigonus* and *C. pubescens*), water melon (*Citrullus vulgaris*), colocynth (*Citrullus colocynthis*), squash melon (*Citrullus vulgaris* var. *fistulosus*), bottle gourd (*Lagenaria vulgaris*), bitter gourd (*Momordica charantia*), ribbed gourd (*Luffa acutangula*), sponge gourd (*Luffa cylindrica*), snake gourd (*Trichosanthes anguina*), wild snake gourd (*T. cucumerina*), *parval* (*Trichosanthes dioica*), *Coccinia indica*, *kundru* (*Cephalandra indica*), galls of *Vitis trifolia*, tomato (*Lycopersicum esculentum*), brinjal (*Solanum melongena*), chilli (*Capsicum frutescens*), papaya (*Carica papaya*), guava (*Psidium guajava*), peach (*Prunus persica*), date (*Phoenix dactylifera*), citrus (*Citrus* sp.) and wild vine with red drupes.

Outside India, it has been reared in gourd (*Lagenaria siceraria*), Chinese melon (*Benincasa hispida*), Oriental pickling melon (*Cucumis melo* var. *conomon*), pumpkin (*Cucurbita pepo*), *Bryonopsis laciniosa*, *Citrullus* sp., *Melothria heterophylla*, *Memordica balsamina*, *Trichosanthes cucumeroides*, *Sechium edule*, *Sycos* (*Sicyos*?), string bean (*Phaseolus vulgaris*), lime bean (*Phaseolus limensis*), mungo or green gram (*Phaseolus radiatus*), hyacinth bean (*Dolichos lablab*), pigeon pea (*Cajanus cajan*), cowpea (*Vigna sinensis* and *V. sesquipedalis*), green pepper (*Capsicum frutescens*), kohl rabi (*Brassica caulorapa*), cauliflower (*Brassica oleracea* var. *botrytis*), leaf mustard cabbage (*Brassica juncea*), *okra* (*Hibiscus esculentus*), mango (*Mangifera indica*), avocado (*Persea americana*), fig (*Ficus carica*), *Passiflora* sp., *Passiflora seemanni*, *Passiflora quandrangularis*, passion flower (*Passiflora edulis* and *P. foetida*), orange (*Citrus sinensis*), sour sop (*Anona muricata*), custard apple (*Anona reticulata* and *A. squamosa*), apple (*Pyrus malus*), pear (*Pyrus communis*), strawberry (*Fragaria chiloensis*). Most of these plants are occasionally or rarely injured. McBride and Tanda (1949), however, have listed broccoli (*Brassica oleracea* var. *capitata*), dry onion (*Allium cepa*), blue-field banana (*Musa paradisiaca* sp. *sapientum*), tangerine (*Citrus reticulata*) and longan (*Euphoria longan*) as the doubtful hosts of *D. cucurbitae* Coquillett. This refers to an induced oviposition study and has no bearing on host material.

Nature and Extent of Damage. From the point of puncture, where the fly has laid her eggs in certain fruits, oozes out a thin but profuse watery fluid which later is transformed into a brown resinous deposit. The larvae that hatch out from the egg bore into the pulpy tissue through what are termed larval galleries. The fruit subsequently rots (Plate III, fig. 3). The young infested fruits of bitter gourd (*Momordica charantia*), sponge gourd (*Luffa acutangula*), *parval* (*Trichosanthes dioica*), snap melon (*Cucumis melo* var. *momordica*) and cucumber (*Cucumis sativus*) get badly distorted.

The fly prefers green and tender fruits of pumpkins as it is not able to pierce the hard rind of the larger fruits. Similarly, some of the gourds with hard rind escape damage. The fly sometimes lays eggs in the corolla and other organs of the flower and the maggots that hatch out of these feed on the flowers and a few have been observed to feed even on the stem of the cucurbit vines. When the maggots feed in the stem, characteristic galls are formed.

The extent of damage that this fly causes to vegetable production in our country is not fully realized. Often more than 50 per cent of the vegetables are either partially or totally damaged rendering them unsuitable for human consumption.

Bionomics. The adult flies are generally long-lived and active. They can, however, be easily caught in tubes placed on them quickly when they are browsing on the leaves. They are attracted in numbers to the pulp and juices of cucurbit fruits when they are exposed by the removal of the rind or by the injury of the fruit. They have also been observed feeding on the cut surface of pear fruit and honey-dew of aphids infesting brinjal throughout summer. In the Hawaiian Islands, flies have also been observed feeding on the flowers of the sunflower and Chinese bananas and on the juice exuding from sweet corn. This species is active and continues to breed throughout the year except for a short period, during the months of January and February when it is very cold. Sometimes egg laying has been observed even during the end of December. There is no doubt that the flies breed throughout the year where the climate is equable. In winter this species also has the habit of congregating under the leaves like *D. dorsalis* Hendel and *D. diversus* Coquillett but generally the population density of this species is more than *D. dorsalis* and less than *D. diversus* Coquillett. In severe cold they hide and huddle together under dried leaves of bushes and trees. In March when the weather warms up these flies are the first amongst the *Dacus* species to be on the wing. In places where the pre-monsoon period (April to June) is hot and dry the flies take shelter under humid and shady places and feed on honey-dew of aphids infesting brinjal or fruit trees. If under such situations they find suitable conditions for their breeding they may oviposit in guava, peach or cucurbit fruits grown as creepers under the shade of trees. Cucurbits are preferred but under exceptional circumstances the flies can breed in other fruits also. During the hot and dry months it is *Dacus ciliatus* Loew that actively breeds on all forms of Cucurbitaceae and the population of *Dacus cucurbitae* Coquillett in the fields is therefore low.

In the rainy months of July and August, the fly is at its peak and causes heavy damage to squash melon (*Citrullus vulgaris* var. *fistulosus*), bitter gourd (*Momordica charantia*), ribbed gourd (*Luffa acutangula*) and long melon (*Cucumis utilissimus*). In other words this

species actively breeds when the temperature falls below 90° F. and the humidity between 60 and 70 per cent. September and October months are passed in bottle gourd (*Lagenaria vulgaris*), ribbed gourd (*Luffa acutangula*), snap melon (*Cucumis melo* var. *momordica*), cucumber (*Cucumis sativus*) and snake gourd (*Trichosanthes anguina*).

During the cold months of November and December, the fly has been observed to breed on *Coccinia indica*, bitter gourd (*Momordica charantia*), sponge gourd (*Luffa cylindrica*) and pumpkin (*Cucurbita maxima*) which are grown in this country up to December or left over as stray creepers in the hutments. The fly has also been observed in certain areas breeding on wild *Cucurbitaceae* (*Cucumis pubescens* and *Citrullus colocynthis*), chilli (*Capsicum frutescens*) and tomato (*Lycopersicum esculentum*) during this particular period. Some of the adult flies live throughout the winter on honey-dew, plant exudations and fruit juices that exude through accidental injury to fruits or plants. The ratio of its population with its associate *D. ciliatus* Loew during September to December largely depends upon the prevailing weather conditions.

Mortality in this fly is also very high mainly because it is more or less specific in its host plant preference. It has already been mentioned that the flies continue to breed even in November and December. During autumn and early winter there are only a small number of cucurbitaceous plants in the fields and the few that are there are very heavily attacked. Naturally, there is not enough food for all with the result that there is either heavy mortality or the individuals that emerge are undersized and weak. In addition to this major factor, mention must be made of the parasitization of the full-fed larvae, when they are about to pupate by a braconid parasite, *Opius fletcheri* Silvestri, from August onwards. The natural parasitization in certain localities is as high as 20 per cent during September and October.

Life History. Biology of this fly has been studied in great detail by Clark (1898), Severin *et al.* (1914) and Back and Pemberton (1914, 1917) in Hawaii, and Fukai (1938) in Japan. Some very interesting observations have been made by these workers. Severin *et al.* (1914) bred as many as 637 flies from a single pumpkin four inches long. Fukai (1938) has observed that the life-cycle of the fly lasts from 21–179 days. He also observed that the adults could survive for over

a year at room temperature if fed on fruit juices. They are inactive at a temperature of 8-9° C. (46·4–48·2° F.). Many survived in an exposure to 4·6° C. to 5·0° C. (23·72 to 41·0° F.) temperature for 128 hours out of doors in winter. Seventeen to 44 per cent of the pupae survive winter. The larvae in fruits and some pupae even survive immersion in water for 36 and 72 hours respectively.

Back and Pemberton (1914, 1917) observed that flies fed on cucumbers began to oviposit 11-12 days after emergence. Renjhen (1949) observed that, in India also, the flies reared on cucurbit juices like that of *Luffa* spp. mature quickly and have a pre-oviposition period as short as 13 days. We have studied many of the obscure points in the biology of the fly that are summarized below.

Emergence of the flies from pupae takes place between 6 and 8 a.m. in summer (April to October) and 9 and 11 a.m. in winter (November to March). Mating has not been observed during the course of the day but like other *Dacus* species, probably it takes place at dusk for a short period. It has a pre-oviposition period of 14 days in August. Other workers have observed that it may range from 9 to 30 days or even longer in winter. In summer, the eggs are laid during the day in shade but in sunshine they are preferably laid during the evening hours. In the act of egg laying the fly walks over the fruit and surveys it quickly by the up and down movements of the palpi and ovipositor selecting a suitable place for oviposition. Having selected the spot it bends its abdomen at right angles to the body or sometimes the abdomen forms an obtuse angle with the head, and the fly gradually inserts its ovipositor by forward and backward movement of the abdomen, and the telescopic extension and retraction of the abdominal segments, aided by the piercing action of the needle-like distal part of the ovipositor. If at this stage the pulp of the fruit is found hard the fly abandons the spot leaving a pseudopuncture and begins its search for a softer spot in its vicinity. Having thus selected and secured a cavity about 2–4 mm. deep in the pulp, the fly makes the wall of the cavity impervious to moisture by a gummy secretion so as to stop the flow of excessive juice into the cavity and consequent injury to the eggs. After this initial precaution the fly becomes almost motionless and lays its eggs in the receptacle prepared by it. The wings remain fully stretched during the act of oviposition. With the ovipositor as its pivot it takes a turn to the right, covering

about one-fourth of the circle, then stops for a while to lay more eggs and then continues its march round till it occupies a position exactly opposite to the one from where it started. That is to say before starting egg laying the head of the fly faced upwards and now it faces downwards. In this position also the fly stops for a while and effects the final delivery of the remaining eggs and moves round either back in the same direction from which it circled or completes the unfinished circle and comes to halt at the place from where it started. The fly before taking out the ovipositor releases a gummy secretion which cements the tissues surrounding the puncture and this cement solidifies as a shiny brown resinous mass around the aperture on the surface of the fruit (Plate III, fig. 1). As soon as the ovipositor is drawn out the fly walks a short distance and pauses for a while to clean the fully extended ovipositor by movements of the hind pair of legs. The whole act of oviposition lasts from about six to eight minutes, half the time being spent in selection of the spot and cleaning of the ovipositor and the other half in actual egg laying. If, however, egg laying is not complete or the fly has to suspend egg laying owing to an apprehension of some danger it may return to the spot after several minutes to complete its oviposition. In the laboratory it was observed that when the pulp of the fruit was exposed for oviposition, the fly at the time of egg laying instead of turning round with its ovipositor as a pivot drew out the ovipositor from the point of insertion and reinserted it in the vicinity of the first puncture. In this way four to six contiguous punctures were visible on the surface of the fruit which led to the same cavity within the pulp. In the case of egg laying on a cut surface of the fruit the fly cleans the legs and inner surface of the wings as well before it finally takes off. Rejected spots unsuitable for egg laying can be made out as slight depressions on the cut surface of the fruit. The act of circling round with its ovipositor as a pivot is performed perhaps to make room for the safe deposition of eggs in the fruit. The number of punctures on the surface of the fruit made by this species is few, in most instances ranging from one to three. Eggs are embedded vertically or slightly slanting and touching each other. They are sometimes laid in two or three planes. This, however, occurs when a number of flies use the same ovipuncture for egg laying. The eggs are laid singly or in clusters of four to ten. Usually there are about a dozen eggs in each puncture, the maximum

number observed being 120 at a time when there was scarcity of host fruits. Compared to *D. dorsalis* Hendel the number of punctures made by this species is usually one and seldom exceeds three because the rind of the growing fruit soon becomes hard.

The number of eggs laid by one female is not exactly known but according to Severin *et al.* (1914) dissections of the ovaries revealed that these contained 22 to 74 fully mature eggs. Van Dine (1907), however, mentions that the number of eggs which the female deposits at one time ranges from five to fifteen. In our experiments, the two females laid 58 and 95 eggs each in their oviposition period of 54 and 14 days respectively during July to the middle of September. Owing to high temperature both the females died abruptly in the middle of September. If the temperature had continued about optimum, these might have laid more eggs. Eggs are not laid daily but at an interval of two to five days or even longer because they are laid as they mature depending upon the availability of food and weather conditions. The number of eggs laid on a single day may vary from one to twenty-six. The egg (Plate III, fig. 2) is white, cylindrical and slightly curved on one side. The incubation period varies from less than 24 hours in summer to six to nine days in winter. The larvae that hatch out bore into the fruit and construct galleries. As many as 50 maggots have been bred from a single squash melon (*C. vulgaris* var. *fistulosus*). Decay of the vegetables is aided by bacterial action. The maggots are full-fed in about three days in summer to three weeks in winter depending upon the season and the rapidity with which the host plants decay as a result of the infestation. The full-grown larva has the peculiar habit of curving itself and springing into the air to a distance by the sudden relaxation of certain muscles. In this way six to eight inches of ground are covered to find suitable places for pupation. The full-fed larva is cream coloured or pale white. Sometimes its digestive tract is dark red or yellow from the contents of the food. The full-grown larvae measure 9 to 10 mm. long and 2 mm. broad across the thorax (Plate III, fig. 4). The larvae are not able to develop in bean pods (certain string beans are suitable for complete pre-imaginal development) or fruit with hard pulp that dries up soon, showing that moist food is necessary for its development. But, at the same time, if the moisture is excessive owing to rapid fruit decay the larva also dies. The

Dacus cucurbitae Coquillett

1. Tender snap melon showing the resinous deposit over the puncture caused after oviposition (natural size). 2. Egg (×18). 3. Damaged melon fruit with the maggots (natural size). 4. Full-fed maggot (×9). 5. Pupa (×9). 6. Female (×9). 7. Male (×9). 8. Braconid parasite *Opius fletcheri* Silvestri.

Dacus ciliatus Loew

1. Squash melon showing the puncture caused by oviposition and the resinous deposit at the site of the puncture (natural size). 2. Egg (×30). 3. Damaged fruit with maggots (natural size). 4. Full-fed maggot (×9). 5. Pupa (×9). 6. Female (×9). 7. Male (×9).

fully-developed maggots leave the fruit through one or two exit holes made in the fruit and pupate in the soil half to six inches deep depending upon the nature of the soil. The pre-pupal period varies from less than six to as long as 24 hours. The pupa is barrel shaped, light brown or pale turning ochraceous as it develops. It is eleven segmented and measures 5·5 mm. long and 2 mm. broad (Plate III, fig. 5). The pupal period takes six to nine days in the rainy season, about three weeks in November and four weeks in December-January. The under-fed pupae measure 5×1·6 mm. and, therefore, the flies that emerge from them are also small. The adult flies (Plate III, fig. 6 and 7) are reddish brown with lemon yellow curved vertical markings on the thorax and fuscous shadings on the outer margin of the wings. The female is easily distinguished by the presence of a tapering abdomen ending in a pointed ovipositor. The adults can live for one to two days without food. If properly fed on the juices of cucurbits, the male is observed to live for 56 days and female 66 days during the monsoon months. Out of the 358 flies reared during July to December, 183 were males and 175 females.

The pest produces several generations in one year. As the broods take from 28 to 66 days to complete their life-cycle during the monsoon months, overlapping broods at this time of the year is the rule.

DACUS (STRUMETA) CORRECTUS BEZZI

Distribution. This species has been recorded in India from Pusa (Bihar), Coimbatore, Guindy and Hagari (Madras), Bilaspur (Madhya Pradesh) and the Punjab.

Food Plants. Mango (*Mangifera indica*), peach (*Prunus persica*), *bael* (*Aegle marmelos*), *ber* (*Zizyphus jujuba*), orange, *Caressa carandas*, *Eugenia michelii* and sandalwood berries.

Bionomics and Life History. Very little is known about the bionomics and life history of the fly. The adults are attracted to newly-opened termitarium.

DACUS (STRUMETA) LATIFRONS (HENDEL)

This species, known as *Dacus* (*Strumeta*) *latifrons* (Hend.), has been recorded from South India and has been bred from snake gourd, cucumber, *Solanum sisymbrifolium* and *Solanum* sp. from March to May.

DACUS (STRUMETA) NUBILIS BEZZI

Dacus (*Strumeta*) *nubilis* Bezzi species occurs in South India and is known to attack *Cephalandra indica* (Cucurbitae) and the possibility of its infestation in other cucurbits cannot be ignored.

DACUS (STRUMETA) NIGROTIBIALIS (PERKINS)

Dacus (*Strumeta*) *nigrotibialis* (Perkins) has been recorded from the coffee-growing areas of South India and infests *Coffea robusta* in March.

DACUS (GYMNODACUS) DIVERSUS COQUILLETT

Dacus (*Gymnodacus*) *diversus* Coquillett can be called the guava fruit fly as the flies are generally found in a large number in the guava orchards.

Distribution. It has been recorded from Coimbatore and Mayavaram in Madras, Bangalore in Mysore, Ahmedabad and Nagpur in Bombay, Dehra Dun and Allahabad in Uttar Pradesh, West Bengal, Shillong in Assam and the Punjab. Outside the Indian Union, the fly has been recorded from Pakistan, Burma and Ceylon.

Food Plants. The fly attacks a variety of plants like guava (*Psidium guajava*), mango (*Mangifera indica*), plantain (*Musa sapientum*), sour orange (*Citrus aurantium*), *jamun* (*Eugenia jambolana*), bottle gourd (*Lagenaria vulgaris*), *Cucurbita pepo*, *Solanum verbascifolium*, wild nutmeg, caddish, Honde fruits (*Cerbera manghas*) and anthers of cucurbit flowers. According to Batra (1953) this fly breeds in the flowers of gourd and *Luffa* sp. and might breed in other host fruits under exceptional conditions.

Nature and Extent of Damage. The damage caused by this species is more or less similar as has been described in the preceding pages. Minor points of differences have yet to be investigated. It is interesting to note that though the fly is found in large numbers in orchards as well as in kitchen gardens, the damage caused by it is insignificant as compared to the damage caused by the same number of other species. It has been observed that the fly breeds freely and completes the whole of its life-cycle in the flowers of cucurbit plants.

Bionomics. This is another interesting fruit fly (Plate II, fig. 4 and 5) which offers a vast field for further research. The flies overwinter

in the adult stage. They are more numerous than the other species as determined when they congregate after dusk under the leaves of mulberry, fig, guava, citrus and loquat in the latter half of October and November. In the deciduous trees when the leaves fall the flies take shelter under evergreen fruit trees like guava, loquat and citrus. As there is a further drop in temperature, the flies hide under the folds of dried leaves of guava and loquat. In spring, the flies become active and are generally seen in orchards basking on the leaves and feeding on the honey-dew of black aphids, *Pterochlorus persicae* Cholodovsky, infesting peach, plum and apricot. The flies dwindle in numbers in the hot months of May and June and with the first shower in July they are seen flying about in small numbers in the vicinity of cucurbit flowers in which they oviposit. The rainy months with their optimum temperature and humidity enable them to complete their life-cycle quickly and there is a steep rise in population. By about this time the loquat trees are in flower and guava and citrus begin to ripen, and the flies are attracted to these hosts from the kitchen gardens where the cucurbit fruits have begun to dwindle in numbers.

Life History. Though this species is found year after year in very large numbers both in the kitchen gardens as well as in the orchards it is astonishing that the life history of this species was shrouded in mystery. This has now been studied in some detail by the junior author (Batra, 1953). We do not know the detailed life-cycle of this interesting species and there is a fertile field for future workers on this particular problem.

DACUS (ZEUGODACUS) HAGENI DEMEIJERE (=*D. CAUDATUS* FABRICIUS)

Distribution. *Dacus* (*Zeugodacus*) *hageni* deMeijere has been recorded from Pusa in Bihar, Calcutta in West Bengal, Shillong in Assam, Dehra Dun, Bhowali, Kumaon and Jeolikot in Uttar Pradesh, Sikkim, Coimbatore in Madras, Bababudin hills in Mysore, Pollibetta and Sidapur in Coorg, Nagpur in Bombay and the Punjab. Outside India, it has been recorded from Nepal, Burma, Ceylon, Java, Malayan States, Formosa and the Philippines.

Food Plants. The fly has been known to attack pomelo (*Citrus grandis*), mango (*Mangifera indica*), sapota (*Achras sapota*), pumpkin

(*Cucurbita maxima*), snake gourd (*Trichosanthes anguina*), *Trichosanthes palmata*, bottle gourd (*Lagenaria vulgaris*), ribbed gourd (*Luffa acutangula*), sponge gourd (*Luffa cylindrica*), cucumber (*Cucumis sativus*), *Citrullus* sp., *Bryonopsis laciniosa* and tomato (*Lycopersicum esculentum*). In Malaya it breeds in wax gourd (*Benincasa hispida*), tomato (*Lycopersicum esculentum*), *Eugenia javanica* and *Luffa cylindrica*. Pomelo (*Citrus grandis*) has been recorded as a host in Burma.

Nature and Extent of Damage. The extent of damage caused by the fly has not been studied but as the species has a wide host range in certain seasons, it is something to reckon with.

Bionomics and Life History. No observations have been recorded on the bionomics of this fly. However, there is a close resemblance between adults of this species and of *D. cucurbitae* Coquillett. There is little doubt that these two species have been confused in life history studies.

DACUS (ZEUGODACUS) DUPLICATUS BEZZI

Distribution. The species called *Dacus* (*Zeugodacus*) *duplicatus* Bezzi has been recorded from Pachmarhi in Madhya Pradesh.

Food Plant. The fly has been reared from peach (*Prunus persica*).

Nature and Extent of Damage. The extent of damage has not been studied but it is not great.

Bionomics and Life History. The bionomics and life history of this species have not been studied.

DACUS (ZEUGODACUS) MACULIPENNIS DOLESCHALL

Distribution. The fly *Dacus* (*Zeugodacus*) *maculipennis* Doleschall has been recorded from Kurseong and Calcutta in Bengal, Pachmarhi in Madhya Pradesh, Coimbatore in Madras. Outside India, it has been recorded from Java and Minbu in Burma.

Food Plants. The fly has been recorded from *cholam* (*Andropogon sorghum*—adults only) in Coimbatore and peach (*Prunus persica*) in Pachmarhi.

Nature and Extent of Damage. The extent of damage caused by the fly has not been studied.

Bionomics and Life History. No observations are on record on the bionomics and life history of the fly.

DACUS (DIDACUS) CILIATUS LOEW

As *Dacus* (*Didacus*) *ciliatus* Loew has been bred in large numbers from melon and as it prefers this fruit to others it is also known as the melon fruit fly. It must, however, be mentioned that the real melon fruit fly referred to by many authors is *D. cucurbitae* Coquillett. Therefore, to avoid confusion it is more commonly referred to as the Ethiopian melon fly.

Distribution. This species is of African origin and has been originally described from Eritrea, but it is now widely distributed in the European countries as a serious pest of melons. In India, the fly has been recorded from Delhi, Lucknow in Uttar Pradesh, Coimbatore, Triplicane, Siddhout, Hagari and Cuddapah in Madras, Poona in Deccan, Surat and Nagpur in Bombay and Jullundur in the Punjab. Outside India, it has been recorded from Pakistan, Europe, Transvaal, Sudan, South-West Africa and Rhodesia.

Food Plants. Different kinds of fruits like musk melon (*Cucumis melo*), snap melon (*Cucumis melo* var. *momordica*), water melon (*Citrullus vulgaris*), squash melon (*Citrullus vulgaris* var. *fistulosus*), bitter gourd (*Momordica charantia*), *Capsicum* sp., long melon (*Cucumis utilissimus*), cucumber (*Cucumis sativus*), sponge gourd (*Luffa cylindrica*), ribbed gourd (*Luffa acutangula*), pumpkin (*Cucurbita maxima*), snake gourd (*Lagenaria vulgaris*), *Cucumis pubescens*, *Cephalandra indica* and *Coccinia indica* are attacked by this fly. In Eritrea it has been known to attack citrus fruits as well.

Nature and Extent of Damage. The nature and extent of damage are not very different from those caused by the melon fly, *D. cucurbitae* Coquillett. The fly has been observed to cause serious damage to cucurbit vegetables. Except for seasonal variations, the intensity of its population is the same as that of its associate the melon fly, *D. cucurbitae* Coquillett. In juicy fruits like squash melon (*Citrullus vulgaris* var. *fistulosus*) a mass of brown resinous deposit (Plate IV, fig. 1) is found at the point of incision made by the female during the act of oviposition. As the maggots feed, malformity characterized by a rugged surface is visible on the fruits of *Coccinia indica*, squash melon (*Citrullus vulgaris* var. *fistulosus*), bitter gourd (*Momordica charantia*), ribbed gourd (*Luffa acutangula*), long melon (*Cucumis utilissimus*), musk melon (*Cucumis melo*) and cucumber (*Cucumis sativus*). The fruit remains attached to the vine till the whole of it is rotted.

Bionomics. The fly is active throughout the year and six generations have been recorded in areas where there is an equable and subtropical climate. The number of generations is less in the north where there is a clear-cut winter season accompanied by a fall in temperature. In these areas the flies are active up to the end of December and overwinter as pupae. The adult flies emerge from the pupae in April and are found flying about in the kitchen gardens in search of cucurbit fruits. The tender fruits that are formed in May are damaged. In Delhi the authors have observed that it is the only species that attacks cucurbit vegetables like *Coccinia indica*, bitter gourd (*Momordica charantia*), water melon (*Citrullus vulgaris*), squash melon (*Citrullus vulgaris* var. *fistulosus*), musk melon (*Cucumis melo*), cucumber (*Cucumis sativus*) and long melon (*Cucumis utilissimus*) in May and June, when the weather is hot and dry. After the first shower in July both *D. ciliatus* Loew and *D. cucurbitae* Coquillett are bred from one and the same fruit but gradually the larval population of the latter increases and that of the former decreases. During the heavy rains this species stops breeding and in autumn when the temperature rises and humidity falls the flies are again found breeding in association with *D. cucurbitae* Coquillett. The latter are, however, found in small number at this time of the year and the flies breed in *Coccinia indica*, bitter gourd (*Momordica charantia*), sponge gourd (*Luffa cylindrica*) and snap melon (*Cucumis melo* var. *momordica*). *Coccinia indica* is the most preferred host that fruits early in summer and late in November and being perennial enables the flies to tide over the period of host scarcity. Very tender fruits hardly measuring 5 cm. × 1·4 cm. are attacked and they bear one to three punctures but as many as eight punctures have been observed on a fruit measuring 7 cm. × 2 cm. This is due to the fact that the flies oviposit in the same fruit over and over again with the result that there is not enough food for the growing maggots. The larvae, therefore, are never full-grown and the pupae are small in size, the smallest pupa measuring 3 mm. × 1 mm. There is heavy larval mortality and the few that successfully emerge are small and undersized. We have observed in the field that at certain periods of the year though there is a keen competition between these two species, *D. ciliatus* Loew and *D. cucurbitae* Coquillett, for survival, there is no indication on the part of one to dominate or exterminate the other. It is astonishing how

both the species survive these adverse times and eventually build up a strong race of moderate population from parents that were more or less weaklings. It may, however, be stated that over 50 per cent of the pupae failed to develop into adults during June in the laboratory owing to drought. Next to *Coccinia indica*, the flies prefer bitter gourd (*Momordica charantia*) and snap melon (*Cucumis melo* var. *momordica*). In early summer the least attacked host plant is the bottle gourd (*Lagenaria vulgaris*); although oviposition has occasionally been observed on the fruit the maggots have failed to develop.

Life History. Cherian and Sundaram (1940) have studied the life history of this fly in Coimbatore and we have also worked out the life history in Delhi. We have observed that the adults emerge in the morning and the pre-oviposition period observed is four days. The female (Plate IV, fig. 6) is very active prior to egg laying and goes over the fruit a number of times to select a spot for egg laying. When the female pricks the fruit with its ovipositor a liquid of white colour oozes out of the puncture. The female, after licking the exudation, flies off but soon returns to feed on the fluid collected in the form of a globule and thrusts her ovipositor in the same spot a number of times to form a cavity to deposit her eggs. At the time of laying eggs the fly becomes motionless with its wings stretched across the body. After about two minutes, it takes a turn to the left covering about one-fourth the circle that it can make with its inserted ovipositor as a pivot. After a short pause of one minute it again moves round to the left and halts at a place exactly in the opposite direction of the one from where it started. After about a minute's pause it moves round and completes the circle and arrives at the place from where it started. After stopping for about a minute it turns round to the right and covers half the circle where it stops for about a minute and turns back the same direction and occupies its original place. Here it pauses for a while and then finally draws out its ovipositor which is held extended till it is cleaned with the hind pair of legs at a short distance from the puncture. This has been observed so far in this species only. The whole process of egg laying takes about seven minutes. The liquid that oozes out of the fruit during the act of oviposition dries up as a brown resinous mass around the aperture (Plate IV, fig. 1). On examination of the puncture, it was observed that a cavity had been formed by the fly within the pulp to accommodate

the eggs. The place all round the cavity is made impervious by a cementing fluid which imparts a brown appearance to the tissues. The eggs are embedded 2·5 mm. deep. The number of eggs laid varied between three to eight for each puncture made. As many as eight punctures have been noted on the fruit of *Coccinia indica* and as many as 22 eggs have been observed in three punctures. The egg (Plate IV, fig. 2) is shiny white, cylindrical, slightly curved and 2·5 mm. in length. The incubation period is two to four days in September and October and very much less in early summer. The larvae feed on the pulp of the fruit. As many as 45 maggots have been bred from a single melon. The maggot is full-fed (Plate IV, fig. 4) within four to six days in October and is 8 mm. long and 1·4 mm. broad. It is then cream coloured and has a jumping habit like that of *D. cucurbitae*. The full-grown larva enters into the soil half to two inches deep for pupation. The pupa (Plate IV, fig. 5) is cylindrical, brownish to ochraceous in colour and is 5·5 mm. long and 2·5 mm. broad. The pupal period lasts six to eight days in summer and is longer in winter. Pupation, however, also takes place within the fruit even as the juice begins to dry up. In this character it markedly differs from *D. cucurbitae* that pupates invariably outside the fruit. The complete life-cycle takes about 15 to 17 days. The flies have six generations under Coimbatore conditions. The adult flies (Plate IV, fig. 6 and 7) are smaller than *D. cucurbitae* and are bright brown or ferruginous brown in colour, with wings hyaline and void of dark markings. Two round dark brown spots are visible dorsally on the fourth abdominal segment (Plate IV, fig. 6 and 7).

DACUS (DACULUS) OLEAE VAR. *ASIATICA* SILVESTRI

Fletcher (1920) records that this well-known pest of cultivated olives in southern Europe is known to occur in wild olives in Cherat, North-West Frontier Province and probably throughout North-West India. So far as is known, it has not yet been observed to attack cultivated olives in India but the olive industry is still in an infant state and there is little doubt that we shall have trouble from this fly as the area of cultivation extends. Pruthi and Batra (1938) also mentioned it to be a pest of wild and cultivated olives in North-West India but it has so far not been reported in large numbers in any locality.

MYIOPARDALIS PARDALINA BIGOT

Distribution. *Myiopardalis pardalina* Bigot has been recorded from Jullundur in Punjab and Pusa in Bihar. Outside India, it has been recorded from the N.W.F.P. and Quetta in West Pakistan, Afghanistan, Mesopotamia, Palestine and Egypt. It is commonly known as the Baluchistan melon fly.

Food Plants. Musk melon (*Cucumis melo*), *Cucumis trigonus*, water melon (*Citrullus vulgaris*), cucumber (*Cucumis sativus*) and vegetable marrows are all attacked by this fly.

Nature and Extent of Damage. The fly selects tender-growing fruits sometimes even ovipositing in the ovaries that have just been fertilized and from which the sepals and petals have not yet fallen. The freshly punctured fruit is conspicuously marked with a reddish brown resinous secretion. When the fruit is severely punctured at several places, growth almost ceases and the fruit begins to rot before the eggs hatch. The tender fruit, if not badly attacked, rapidly increases in size. In about four days the position of the eggs caused by the growth of the melons appears altered and instead of lying just below the rind of the fruit or embedded in the pulp appears about three-fourths of an inch deep from the skin with only a hair-like line leading to the minute aperture caused during the act of oviposition. In cucumber and vegetable marrows, the maggots cause distortion by tunnelling and feeding in the pulp. The female fly, however, cannot successfully puncture the rind of a healthy melon of over four days' growth, but if it does and the fruit is about ten days old the aperture in the rind is obliterated and with this all traces of oviposition and the young maggots that feed and make their way inside the fruit through the pulp disappear.

The maggots cause very little damage to edible pulp and feed on the seed and its surrounding soft and spongy pulp, if they are prevented by any means from cutting their way out. But once the rind is punctured by the full-fed maggot the fruit completely loses its market value. Moreover, the fruit itself begins to deteriorate, ferment and finally rot. In a normal season the percentage of attack is less than 5 per cent whereas in a bad season as much as 20 per cent of the fruits may be attacked in the peak period of July. The *sardah* melon, because of its soft skin, is very susceptible to attack by this species, but can be saved by covering the melon with earth. Musk melon is

also equally susceptible and as it cannot stand covering by earth this pest greatly limits its cultivation. The *Herati* variety which is a late ripening variety escapes damage. The *hindwana* or water melon is occasionally attacked. If it is not punctured at many places and the growth is not arrested very much, the young fruit recovers because the maggots are drowned in the juice of the fruit. Only under-developed flies emerge from the badly attacked and stunted fruit.

Bionomics. The fly is active in summer and overwinters in the pupal stage from September to April. Pupation may, however, commence earlier than September in certain years due to fluctuation in weather conditions. From April when the fly hatches out of the pupa to the time when the melon or other food plants begin to bear fruit, the fly feeds on honey-dew secreted by aphids on peach, pear and other trees. The fly is most active in July when the duration of its life-cycle is the shortest, about a month. The pest completes two to three generations before it finally pupates in September for its long winter rest. In severe winter accompanied by a heavy snow-fall a large number of these overwintering pupae perish, resulting in a mild attack during the following summer.

Life History. Cleghorn (1914) has given some details on the biology of this melon fly which he studied in Peshin, Quetta. Pairing starts soon after the flies emerge from the pupae. The female generally selects tender fruits about two to three days old for oviposition. It is very interesting to note their ability to select tender fruits. The fly cannot puncture the rind of a healthy fruit of over four days' growth. The location of the puncture on the rind is revealed by a small accumulation of reddish brown gum as described before, which, however, dries and falls off in a few hours. At this stage, it is difficult to find whether a melon has been punctured or not. The fly lays eggs in the morning during warm sunshine. She bends her abdomen at right angles to the rind in the act of oviposition. Eggs are laid just below the rind and are embedded in the pulp. The number of eggs laid at one time averages five. The maximum number of eggs laid in a single fruit has been observed to be about 130 which naturally have been laid by more than one fly of this number. Only about half a dozen maggots reach maturity and emerge as adults. When the fly lays eggs in fruits more than four days old, the maggots that hatch out of these eggs bore their way towards the core and get

drowned in the juice of the pulp. A few (three to five) maggots appear not to affect the growth and development of the melon. If, however, a larger number of maggots hatch and develop, the fruit becomes stunted and later deteriorates. The incubation period of the egg is about four days. The maggots that hatch out feed on the seeds and pulp surrounding them in the centre of the fruit. The larva is full-fed in about a fortnight. The full-grown maggot cuts a circular hole and deserts the fruit for pupation either in the soil or just below the melon on the surface of the soil. The maggot constructs a tunnel to protect itself from the fruit juice that accumulates by gravitation as it feeds its way upwards. If, however, that fruit is turned over, the maggot has to leave off feeding and begin constructing another gallery upwards and if at this stage again it is turned, it has to re-construct a new gallery. It often happens that due to sheer exhaustion the maggot pupates in the core. The fruit growers in Baluchistan practise this method and they prevent the full-grown maggots from boring their way outside for pupation. The market value of the fruit is thus not lost though the consumer has to take his chance that an apparently healthy fruit he may purchase in the market may contain an assorted sample of pupae and sometimes maggots also. The pupae are light and float on water. During the monsoon many of them are washed away and dispersed to new localities where they start their life-cycle anew. It has been observed that the pupae can stand submergence in water for a long period without injury. A study of this aspect showed that they could stand this submergence for two to three weeks. It is not clear what Cleghorn meant by this submergence. Probably he meant their floating on water for a number of days, as the pupae are light and not heavy enough to sink. The pupal period lasts for 13 days in summer and over six months in winter. The adult flies that emerge can be kept alive for three to four weeks when fed on melon fruit juice.

CARPOMYIA VESUVIANA COSTA

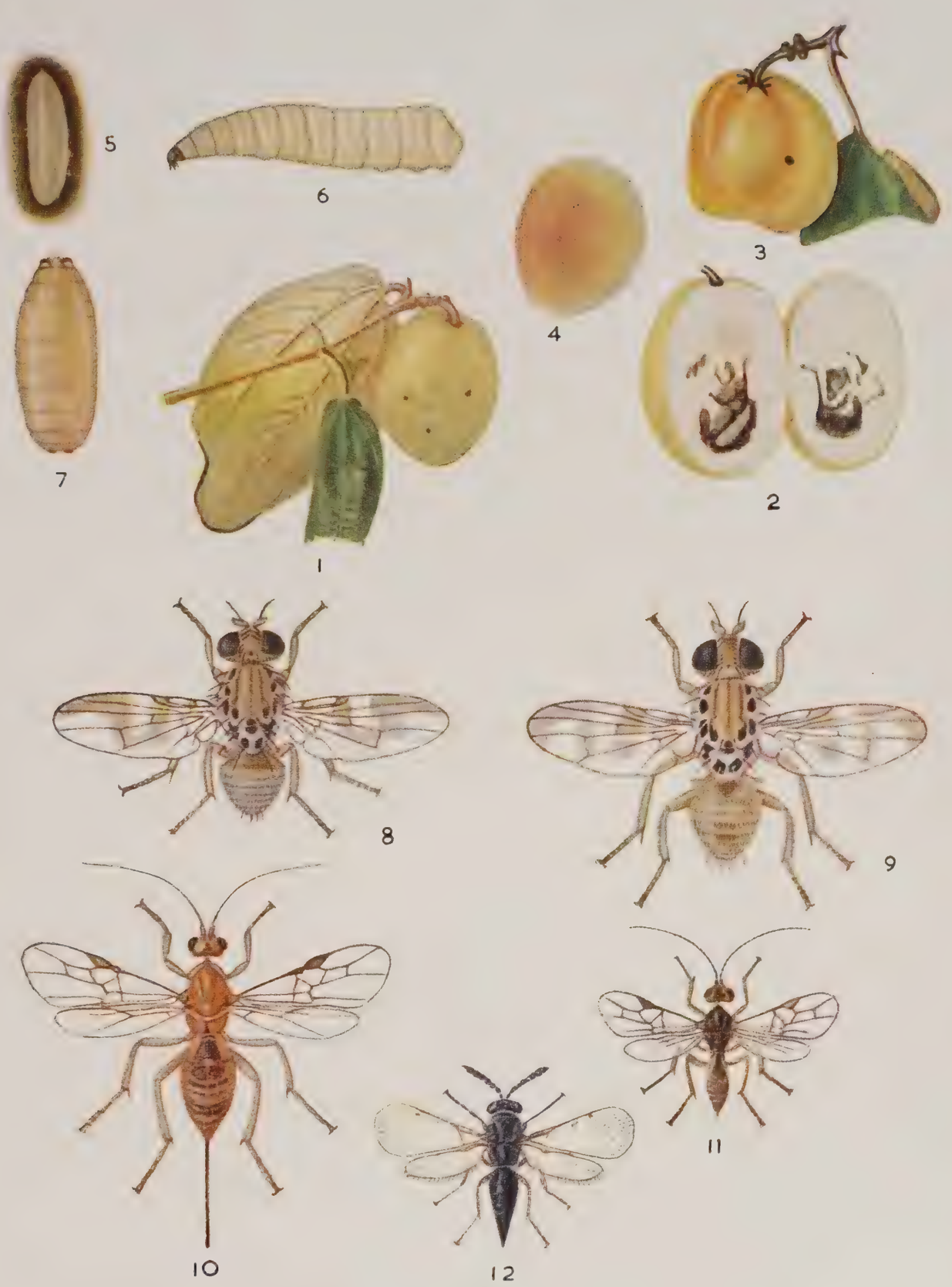
Distribution. The fly *Carpomyia vesuviana* Costa has been recorded from the Punjab, Delhi, Kanpur and Banaras in Uttar Pradesh, Pusa in Bihar, Calcutta in West Bengal, Satna in Madhya Pradesh, Coimbatore and Haddagali in Madras, Poona in Deccan and Baroda

and Nagpur in Bombay. Outside India, it has been recorded from West Pakistan, Dalmatia and southern Italy.

Food Plants. The fly damages the fruit of *ber* (*Zizyphus jujuba* and *Z. nummularia*) in India and that of *Zizyphus sativa* in Italy.

Nature and Extent of Damage. The fly inserts its ovipositor into the fruit to lay eggs. The puncture caused in the act of oviposition is visible through the gummy secretion left around the aperture. The growth of the fruit at the spot where eggs have been laid ceases with the result that the surrounding tissues grow up and give the fruit a rough appearance (Plate V, fig. 3). The puncture gets secondarily located in a slight depression (Plate V, fig. 1). The minute aperture appears as a dark spot when viewed from a distance. The maggots as they hatch bore their way to the interior of the fruit, and in so doing form reddish brown galleries. As they grow they feed on the pulp which soon begins to rot and turns dark brown. The whole fruit smells offensive. A single maggot is enough to render the fruit totally unfit for human consumption. The damage caused by this fly is decreasing significantly the total production of this delicious fruit liked by the rich and the poor alike, both in Delhi and in many other parts of India.

Bionomics. The seasonal activity of this species is different in many ways from that of the *Dacus* species. The latter is mostly active in summer. During winter it is either inactive or where the winter conditions are severe it overwinters in the pupal stage. In the case of the *ber* fruit fly, however, the activity commences from autumn and continues through winter and spring. It hibernates from April to August in the pupal stage. The peak damage to *ber* is observed in February-March when almost all the late ripening varieties of *ber* are attacked. During this period owing to the great density of the population, individual fruits are punctured more than once by the same or different flies with the result that in each fruit sometimes 12 to 18 maggots are found though in autumn one does not find more than one or two maggots in one fruit. The adult flies (Plate V, fig. 8 and 9) are very active and fly fast. The flies seem to have prescience of approaching danger and fly away in good time. The female flies, however, can be caught easily while in the act of oviposition. The adults are long-lived. The pest remains in the soil as pupa in the summer and during the early monsoon period. The



Carpomyia vesuviana Costa

1. *Ber* fruit showing oviposition punctures (natural size). 2. Damaged fruit with maggots (natural size). 3. Rugged fruit showing the exit hole of the maggot. 4. Exit hole of the parasite. 5. Egg (×30). 6. Full-fed maggot (×9). 7. Pupa (×9). 8. Female (×9). 9. Male (×9). 10 and 11. Braconid parasites (×9). 12. Eulophid parasite.

Acanthiophilus helianthi Rossi

1. A damaged bud (natural size). 2. A dissected bud showing advanced stage of damage (natural size). 3. An egg-mass on a leaf (×4). 4. The egg (×16). 5. The full-grown maggot (×10). 6. The pupa (×10). 7. The adult fly (×10).

adults emerge from the latter half of August to mid-November. In certain years due to wide variations and fluctuations in climate they emerge a little earlier but these generally die not only due to the absence of host material but also due to uncongenial environmental conditions. These flies are smaller in size. The period of normal emergence of the *ber* fruit fly synchronizes with the blossoming and formation of fruits by the *ber* tree. The fly attacks the fruit in November when the fruit is very small and tender. Two to three broods have been observed from November to April in Madhya Pradesh where winter conditions are not so severe. The authors have observed only two broods in Delhi where the winter is prolonged and severe. One characteristic feature of this fly is that it is monophagous in habit and it has been bred only from the *ber* fruits so far (*Z. jujuba* and *Z. nummularia*). The fleshy fruits are preferred to the non-fleshy ones because of their abundance of pulp. *Z. nummularia* begins to flower in July-August and, by the beginning of September, tender fruits are formed. It may, however, be stated that a few of the flies that emerge at this time mostly die. In very few cases there may be successful oviposition and development. The damage caused is, however, negligible.

Life History. Khare (1923) has recorded some observations on the life history of this species. The detailed life history has not been worked out so far but the junior author has now studied its biology in some detail (Batra, 1953). The male fly (Plate V, fig. 9) is slightly bigger than the female. The pre-oviposition period of the fly has been observed to be about a month. The female fly (Plate V, fig. 8) punctures the fruit a number of times with her ovipositor to form a cavity to lay her eggs. In each cavity one to two spindle-shaped creamy white eggs (Plate V, fig. 5) are deposited 1 mm. below the rind of the fruit. As soon as the eggs are laid the fly withdraws its ovipositor and covers the aperture (Plate V, fig. 1) with a light brown resinous secretion. The incubation period of the eggs is two to three days. The maggots feed their way toward the endocarp. The freshly attacked fruit is found riddled with galleries (Plate V, fig. 2). The maggots feed on the pulp and cause decay which gives an offensive smell. As many as 18 maggots have been reared from a single fleshy *ber* fruit. The larva (Plate V, fig. 6) is full-fed in seven to ten days. The full-grown maggots cut one or two circular holes in the epicarp and

come out for pupation. They are creamy white in colour and can jump six to nine inches high covering the same distance at each jump to find a suitable place for pupation. Pupation takes place two to three inches in soil. Pupae (Plate V, fig. 7) are ochraceous in colour. The pupal stage lasts from 14 to over 300 days which is an extraordinary feature with this species. The shortest life-cycle from egg stage to the adult is about 24 days.

ACANTHIOPHILUS HELIANTHI ROSSI

Distribution. In India this pest has so far been recorded only from Delhi. Outside India, it has been recorded from the Canary Islands, the Mediterranean region, Central Europe, N. Africa, Egypt, Sudan, Eritrea, Asia Minor, Persia and Central Asia.

Food Plants. The fly attacks safflower (*Carthamus tinctorius*). Other food plants that have been recorded as attacked by this species outside India are *Onopordon illyricum*, *Silybum marianum*, *Cnicus lanceolatus*, *Leuzea conifera*, *Amherboa lippi*, *Centaurea aegyptiaca*, *C. jacea*, *C. ornata*, *C. pallescens* and *C. rhenana*.

Nature and Extent of Damage. The maggots feed upon the essential organs of the florets and even bore into the thalamus. The infested bud (Plate VI, fig. 1) begins to rot and the offensive smelling fluid oozes out from its apical portion and gives it a saturated appearance. If such a moist bud is squeezed between the fingers, the offensive fermented liquid along with one or two maggots come out of the bud. Furthermore, in an advanced stage of the attack, the florets become black (Plate VI, fig. 2) presenting an emaciated and withered appearance. As a result of the damage caused by the fly the buds either open partially or fail to open altogether. In some varieties such as N.P. 30, 90 per cent of the buds are damaged. As the cultivation of safflower is now being considerably extended in India both for the dye obtained from its flowers and for the oil obtained from its seeds there is danger of the spread of the pest throughout the safflower-growing tract through distribution of pupae that get mixed up with the seed.

Bionomics. The fly is very active from March to May and causes maximum damage to the crop during this period. It has been observed in Delhi where several varieties are under trial that the less spiny or the non-felted varieties and those that flower early in the

season are more susceptible to attack by this pest than the late ripening and felted varieties. The fly has been observed to undergo three generations from the time it makes its first appearance in the field till the crop is harvested. In certain years, however, another generation is passed in the terminal shoots before the flowers are formed. In cases like this, it is obviously the first generation, and there are altogether four generations in that particular season. Where the first generation is passed in the terminal shoots, it starts from about the middle of December and lasts till the second week of February. The second generation lasts from the middle of February to the first week of April, the third from the beginning of the second week of April to the end of the third week and the last from the fourth week of April to the first week of May. After the cultivated varieties of safflower have been harvested, the pest migrates in large numbers to wild safflower that grows in abundance along the water channels. The wild safflower serves as an excellent alternate host in the off-season. The adults when fed in the laboratory on peptone, yeast and sugar live for about ten days. One male lived as long as five weeks. The fly is kept in check to some extent by a number of hymenopterous parasites and neuropterous predators. These will be dealt with in detail later. Ecological studies under controlled conditions showed that while the fly could stand extremes of temperature, breeding stopped completely when the temperature went beyond 32° C. Late varieties are less attacked since it gets too hot in the month of May.

Life History. Pruthi and Bhatia (1940) studied the biology of the fly in some detail. The adult fly is ash coloured with light brown legs and can be spotted easily in the act of oviposition. It lays eggs in the field from sunrise to about noon. The fly prefers a young bud on which it walks over warily a number of times, then pricks it at several places with its black shiny ovipositor to select a suitable place for egg laying. The behaviour of the female in the actual process of oviposition was observed different in several respects from the other common species of *Dacus* fruit flies. The female fly slightly bends her abdomen and her ovipositor and makes an obtuse angle with the surface of the head; the fly is absolutely still during egg laying and appears as though dead. The whole act of oviposition takes about two minutes. After the egg laying the female lashes her

ovipositor up and down in the air and cleans it with her hind pair of legs before retracting it into the tip of the abdomen. The eggs are laid in a cluster (Plate VI, fig. 3), the number in the cluster varying from 6 to 24. The egg (Plate VI, fig. 4) is cylindrical and measures 1·2 mm. long and 0·2 mm. broad across the middle. The egg hatches in about 24 hours. The maggot (Plate VI, fig. 5) is 12-segmented. When full-grown it measures 5 mm. long and 1·5 mm. broad across the middle. The larval stage lasts about a week. Pupation generally takes place in the flower bud. The pupa (Plate VI, fig. 6) is black, barrel-shaped and measures 2·5 mm. long and 1·79 mm. broad. The pupal stage lasts about seven days. The adult fly (Plate VI, fig. 7) emerges through a hole in the bud cut by the larva before pupation.

CHAPTER III

CONTROL MEASURES

There is no family of insect pests, in which control measures are as difficult as in the Tephritidae. In many cases the study of the biology of the insect has offered some clue for its effective control. Some weak link in the life history of the pest is discovered and this is exploited by the economic entomologist. Here, however, the study of the biology of the pest offers no effective clue as the larvae live in fruits, vegetables, nuts, or in the buds of the growing plants and, therefore, any insecticide that may be applied in the form of dust or spray cannot reach them. The economic entomologist is left with the only safe method of trapping the adult flies. He can also use insecticide applications in controlling adult populations. In some quarters, there is a feeling of diffidence as well as doubt whether a pest could be effectively controlled in the adult stage. But there is little doubt about the efficacy of this method of control. Insects multiply in geometrical progression and even if only two or more viable females are left in each generation above the normal, the population, in the absence of natural enemies, would assume, at the end of a few generations, such proportions as to constitute a menace. Therefore, the trapping of the adult flies in large number, especially before they start laying eggs, is best to reduce the incidence of the pest population.

It has already been mentioned that, with very few exceptions, the full-fed larvae come out of the fruit and pupate in the soil. At about this time they are attacked by hymenopterous parasites belonging to the families Braconidae and Chalcidoidea. The natural parasitism that occurs in nature also serves as an adjunct to the chemical methods that we may employ in reducing the population of the pest.

The habits of adults before they begin laying eggs have to be studied in detail to devise suitable control measures. For instance, the adult flies after emergence and mating go on feeding on honeydew and juice of split or accidentally damaged fruits before they begin to lay eggs. This is a vulnerable period and sweetened bait-spray should be used at this time.

The various methods of control employed by economic entomologists with a measure of success all over the world to control fruit flies are the following:

1. Mechanical methods
2. Cultural methods
3. Physical methods
4. Chemical methods
5. Biological methods
6. Legislative or quarantine measures

Let us now discuss in detail how each one of the methods mentioned above could be applied for the control of the various species of fruit flies that damage fruits and vegetables grown in our country. The species that have been dealt with in this paper are the following:

1. *Dacus* (*Strumeta*) *dorsalis* Hendel
2. *Dacus* (*Strumeta*) *zonatus* (Saunders)
3. *Dacus* (*Strumeta*) *cucurbitae* Coquillett
4. *Dacus* (*Strumeta*) *correctus* Bezzi
5. *Dacus* (*Strumeta*) *latifrons* (Hendel)
6. *Dacus* (*Strumeta*) *nubilis* Bezzi
7. *Dacus* (*Strumeta*) *nigrotibialis* (Perkins)
8. *Dacus* (*Gymnodacus*) *diversus* Coquillett
9. *Dacus* (*Zeugodacus*) *hageni* deMeijere
10. *Dacus* (*Zeugodacus*) *duplicatus* Bezzi
11. *Dacus* (*Zeugodacus*) *maculipennis* Doleschall
12. *Dacus* (*Didacus*) *ciliatus* Loew
13. *Dacus* (*Daculus*) *oleae* var. *asiatica* Silvestri
14. *Myiopardalis pardalina* Bigot
15. *Carpomyia vesuviana* Costa
16. *Acanthiophilus helianthi* Rossi

MECHANICAL METHODS

1. Observance of Orchard Sanitation

(i) Removal and Disposal of the Fallen Fruits: One of the most vulnerable stages in the life history of the fruit fly is the larvae inside the fruit. It is, therefore, important that as many larvae as possible should be destroyed at this stage. It has been emphasized before that, to prevent the build-up of a large population later in the

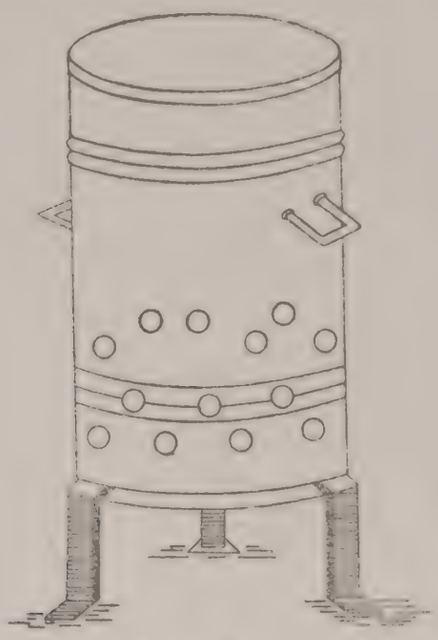
season, the initial progenitors of this population should be destroyed. Therefore, all the infested fruits that fall on the ground should be collected and buried deep in the soil and the earth well pressed on the fruits collected and incinerated. It is essential that the layer of the soil over the infested fruits that have been collected and put in the pit should at least be two feet deep. Otherwise some of the flies may escape. This is one of the essential practices in orchard sanitation that should be scrupulously observed. If there is slackness in the observance of this practice the odour emitted by these fallen fruits attracts flies and increases the danger of further infestation. If during a gale or a strong wind both infested and uninfested fruits fall on the ground, the uninfested fruits should be carefully segregated from the infested ones and either sold or used for preparing by-products like jam, juice, etc.

In 1937, there was a severe epidemic of fruit fly, *D. dorsalis*, in Kurrum Valley, Parachinar (N.W.F.P., Pakistan). The junior author observed that it was almost impossible to obtain a single fruit free from the maggots even in May which is generally the beginning of fruit fly cycle in the hills. All the infested fruits were promptly collected and buried deep in the soil. By this measure all the early varieties of fruits like apricot, plum and peach were saved and marketed without any fruit fly infestation. This operation was carried out regularly for several years till the danger of infestation by this fruit fly was brought below pest proportion.

While the disposal of the fallen fruits in summer is essential it may be mentioned that the same precaution should be applied to the winter fruits which serve as alternate hosts to these flies during such months where the flies breed owing to mild cold weather. During this period the infestation is not large and if the measures described above are carried out it is sure to yield dividends in the form of lower populations, lesser infestation and, therefore, greater yield of fruits. If the infested fruits have not begun to rot, they may be fed to cattle after taking precautions that the infested portion of the fruits with maggots is removed and buried deep in the soil. In some fruit-growing countries like Australia a novel but cheap and effective method is employed to kill the maggots in the infested fruits. Ordinarily the infested fruits are buried deep, but if the quantity of infested fruits

is considerable and the degree of infestation not severe, the fruits can be used either as material for compost or feed for pigs.

In cases like this, the maggots are placed in an incinerator. The incinerator consists of 40–45 gallon drums in which the top has been removed. The bottom and the sides of the vessel are perforated with draft holes one inch in diameter and five to six inches apart to a height of about two feet. Four stout and short pieces



Incinerator

of pig-iron rods which can serve as legs are attached to the drum at the bottom. The drum can even stand on a few bricks. The drum is provided with two wooden handles at about the middle for lifting it from the fire or for carrying it from place to place. A few pieces of wood are placed under the drum and a good fire is built up. Now the infested fruits are slowly dropped in the drum till the drum is covered. The hot draught of air kills the maggots. If the quantity of fruit is large a second drum with the bottom removed is placed over the first and tightly fitted. This also increases the intensity of the draught. Both E.D.B. (ethylene dibromide) fumigation and vapour heat treatment prescribed for infested fruits provide a safe medium for destroying insect infestation without impairing the quality of fruits.

(ii) Picking of Under-sized Fruits left over on the Tree after Harvest: Orchard sanitation needs care in respect of the fruits that are left unpicked on the tree. These may either be missed fruits, or under-sized fruits or fruits that are out of reach in the tender

branches. Of these three categories, the one of under-sized fruits is the most dangerous and becomes the focus of later infestation. The other two categories of fruits mentioned above will soon fall on the ground and may be picked up and buried. We may make particular mention here of the loquat where the undeveloped ones stick on to the tree and never fall on the ground. The flies breed in these after the close of the season.

It may be mentioned that cucurbit plants in the kitchen gardens as well as in the field after the summer season are left grown in the hope that these may yield some more vegetables. These vegetables are not always of good quality as they are produced out of season. The greatest danger of producing such fruits for a little gain is their becoming a focus of further infestation and carry over the flies like *D. cucurbitae* and *D. ciliatus* to summer. This practice cannot be too strongly condemned.

2. Destruction of the Adult Flies

As already stated the adults of *D. dorsalis*, *D. cucurbitae* and *D. diversus* species have the habit of congregating in large numbers varying from a dozen to 3,000 flies under the leaves of evergreen fruit trees like guava, loquat and citrus from November to February when the infestation is less and the flies collect to overwinter in the adult stage. During the night and in the early morning hours depending upon the intensity of cold, the flies congregate in numbers at suitable places for protection against cold. When the atmosphere warms up and is pleasant they disperse and actively fly about. Thousands of flies can be destroyed by catching with hand nets or insecticide. During December when there is a further drop in temperature these flies protect themselves under the folds of dried leaves as their wing muscles are benumbed by cold. Indeed in severe cold they are even unable to make short flights and at this time large numbers of them can easily be caught by hand, crushed or destroyed. It was found that in November the majority of the flies present were *D. dorsalis*. In December, *D. cucurbitae* were killed in a greater number and it was *D. diversus* which predominated in January and February. Large-scale insecticide operations will be profitable and much quicker and effective where facilities for the application of insecticides for killing the flies are available.

3. Protection of the Fruit by Bags

Sometimes, the fruits are protected against the attack of flies by using paper or cloth bags. The junior author carried out some experiments on the use of bags in the pear orchard at the Agricultural Research Station, Tarnab Farm, in 1940, against the attack of *D. dorsalis*. The paper bags used were of two kinds, namely, butter and tissue papers. The cloth bags were made of grey drill. Each fruit was covered with one of the bags mentioned above. It was observed that the paper bags warded off the attack better than cloth bags. The cloth bags prevented oviposition by flies as long as they covered the fruits loosely. When, however, the rains made the bags wet as a result of which they stuck to the fruits the flies were observed to oviposit into the fruits through the wet cloth. It may also be stated that the papers get damaged and torn when there is heavy rain accompanied by storm or gale. Protecting the fruits by bagging is not economical. Sometimes each tree may contain about 1,200 fruits and it is unthinkable that in a large orchard each fruit can be covered with a bag. Moreover, the sunlight, that ripens them and makes them valuable and more nutritious, is cut off. This method, however, can be used by householders who grow one or two trees or fancy vegetables for domestic consumption as here the question of sentiment of saving their crop plays a more important rôle than the question of economics. Even economically it may prove to be a sound proposition as the householders have to deal with only one or two trees at the most and the same bags can be used for many seasons.

CULTURAL METHODS

1. Destruction of Pupae

It has been mentioned earlier while describing the life history of some species of flies like *D. dorsalis*, *D. ciliatus*, *D. zonatus* and *Myiopardalis pardalina* that the pupae of these flies pass their pupal stage in the soil during the cold weather, specially in January and February. If during these months the soil in the orchard is turned over or given a light ploughing a large number of these pupae could be exposed and will become prey to parasites, predators and birds. A large number die also of mechanical injury in the course of ploughing. The pupae of the *ber* fruit fly, *Carpomyia vesuviana*, remain under the

soil in the vicinity of jujube or *ber* trees from May to August and, therefore, if the soil around these trees is ploughed up, a large number of the pupae that form later the nucleus of the myriads of flies that we come across late in summer can be destroyed. It may be emphasized here that turning over the soil not only results in the destruction of the pupae but also aerates the root system thus making the trees healthier.

2. Turning over the Melon Fruit

In the case of *sarda* melon there is a peculiar practice popular among the melon growers in the country-side round about Quetta to prevent the fruit from being tunnelled and damaged by *Myiopardalis pardalina* maggots. The fruit is turned daily for about six days after it has grown for about a fortnight. If a fruit has become stunted this practice does not help much because as the fruit is rendered less luscious the maggots bore in several directions. This practice is only helpful when the maggots are few which is generally the case when a well formed normal fruit is about a fortnight old and the maggots either get themselves drowned in the juice or forced to pupate inside by turning the fruit over every day. This practice has been mentioned in detail when describing the biology of the pest. Growers may try this simple method in the case of melons attacked by *D. cucurbitae* and *D. ciliatus* in our own country. It is possible that many thousands of melons may be saved in this way.

A practice prevalent in Quetta to protect the *sarda* melon from the attack of fruit fly, *Myiopardalis pardalina*, is to cover the fruit with earth for about a fortnight. During this period the rind of the fruit gets sufficiently hardened to prevent the flies from puncturing the rind for oviposition. It has been observed that no other harm results to the fruit than a slight bleaching of the rind. This is, however, more than compensated by freedom from infestation and there can be little doubt that an intelligent customer will value this more than the colour of the rind that might delight the eyes but not the palate.

PHYSICAL METHODS

Heat Treatment. Hitherto only one method of physical control has been practised in regions where fruit fly menace is serious. It is possible that, as our knowledge about the habits of the flies increases,

other physical methods of control could be successfully applied to control the pest effectively. The one method now employed by economic entomologists is briefly described.

The damage by the fruit fly is sometimes so sporadic and acute that all the fruits in an orchard are attacked simultaneously. Usually when such fruits are dumped into the market or despatched to distant trading centres the maggots hatch either in the transit or at the place of destination. The loss to the seller is heavy and the cultivator loses his prestige. To avoid loss like this certain experiments have been conducted in America and Australia with success in the case of citrus and other fruits. The fruit is heated to a temperature between 110° and 112° F. and is kept constant at this temperature for about eight hours in an atmosphere saturated with water vapours. It has been found that this temperature is effective against the eggs and larvae of the Mediterranean fruit fly, *Ceratitis capitata*, without damaging in any way the flavour or the eating qualities of the fruit. It might be asked whether fruits containing dead eggs or maggots could be sent to the market for sale. It may be emphasized that *Ceratitis capitata* maggots hatch out in the rind before boring their way into the pulp. There appears to be no harm in saving such fruits where the maggots or eggs are only in the rind, as these fruits could easily be used by the jam making industry.

CHEMICAL METHODS

The chemical or the insecticidal methods of control of fruit flies fall under three main heads:

1. Spraying the adult flies with suitable insecticides,
2. trapping of the adult flies by means of chemical attractants, which is based on the principle of chemotropism; and
3. bait-spray which in essence consists of an insecticide mixed with a bait which is usually some kind of syrup.

Let us now discuss each of these methods in greater detail.

Spraying with Insecticides. It has already been mentioned in this paper that the flies have a habit of congregating in numbers under the leaves of fruit trees during the night and cooler hours of the morning in autumn and spring. As the temperature rises during the day they either disperse in search of food or are active in laying eggs. During this time flies can be killed in large numbers by the

application of a suitable spray. The one that has met with success is the diesel oil emulsion having the following formula:

Diesel oil	.. 1 gallon	}	Stock solution
Soft soap	.. 1 lb.		
Water	.. 1 gallon		

This stock solution should be diluted eight times with water before spraying.

It has been observed that in the case of fruits having soft skin like the guava, the diesel oil emulsion sometimes causes slight blotches on the fruit. Pyrethrum and organic synthetic insecticides like DDT, BHC, parathion, chlordane, etc., are popular in the U.S.A. and other countries. Suitable concentrations of these insecticides and their correct application are yet to be worked out in India. Even in the U.S.A. and Australia the use of organic insecticides that are very poisonous is still in an experimental stage.

Chemotropism. Insects are attracted to the smell of certain chemicals and essential oils. The use of traps baited with some chemical and kept in orchards where they will attract adult flies in large numbers is one of the universally established methods of control. We have at the present a gap in our knowledge of the factors that govern this phenomenon of attracting large numbers of flies. An attractant which is very successful in one country against a particular species is not bound to give the same result in another country against the same species. A proprietary product that is sold in the market by the name of clensel and which attracts either sex of *D. dorsalis* in large numbers has been found to be successful in N.W.F.P. Hutson (1938), however, observes that clensel is a failure against the same species in Ceylon.

The chemicals also act differently on different species. Ammonia which attracts *Dacus* species was found by Ripley and Hepburn (1931) to repel the Natal fruit fly (*Ceratitis* (*Pterandrus*) *rosae* Ksh.). Thus the success or failure of any chemotropic response depends upon several factors including the species of the fruit fly that we are dealing with. More investigations have to be carried out to put the control measures used on an empirical way now on a rational basis.

Citronella oil, liquid ammonia, vanilla, Jarvis lure (ammonia+ vanilla in water), pollard mixture ($\frac{1}{2}$ lb. bran, $\frac{1}{2}$ lb. borax and 10 lb. water), ammonium carbonate, ammonium sulphate, ammonium nitrate,

clensel, beeco, molasses, eugenol, methyl-eugenol, iso-eugenol and fruit juices are some of the attractants usually employed in different countries with partial success. The dosage generally recommended is about 10 drops or 0·5 to 2 cc. to a pint of water. This is sufficient to disseminate odour for about a week to entrap the fruit flies. Before we recommend the best lure for the control of our major fruit fly pests let us make a brief but passing review of our observations in the field of some attractants that we used and the different species that were attracted.

Dacus dorsalis (pest of loquat, apricot, peach, pear, mango, guava, etc.) is attracted in a large number by citronella, clensel, pollard mixture, vanilla, liquid ammonia, bay oil, iso-eugenol, methyl-eugenol, flowers of papaya, Australian cycad and *Colocassia antiquorum*. Except in the case of clensel and pollard mixture only the male flies are attracted. In the case of clensel, the percentage of females ranges from 50 to 60 whereas in the case of pollard mixture the percentage is much less. The junior author conducted a number of trials in the N.W.F.P. with liquid ammonia, pollard, vanilla and citronella oil for trapping the species. It was observed that clensel proved to be the most effective of these attractants. About 60 per cent of the total flies attracted were females. In the trial with different kinds of traps like clensel, earthen bowl, cigarette tins and brown traps, it was observed that clensel and brown traps made of glass were better than the other two. Between clensel and brown traps the former was easily the better. Pruthi and Bhatia (1938) tried clensel and other attractants and observed that clensel in the ratio of 1 : 20 was more effective than the weaker dilutions. This conclusion was arrived at from the number of flies attracted by different strengths of dilutions. The junior author observed that the effectiveness of clensel depends upon the climate to a certain extent. The adult flies were attracted to clensel only in summer. During the monsoon in Kurrum Valley (Parachinar, 6,000 ft.) no flies were attracted. This shows that the problem of fruit fly control is extremely difficult and further investigations are necessary before the control measures can be rationalized. It should not, however, be assumed that the control measures which attract only males are not of any value. The attractants if kept at about the time of emergence of the adult flies, a large number of the males will be attracted and a small number only be left to mate with the females.

The latter, therefore, may not be able to lay eggs. This fly is definitely attracted to citronella, methyl-eugenol, kerosene, and a fermented lure of brown sugar, yeast and vinegar. In Hawaii, however, it has been recorded that the male flies are attracted to the foliage of a small bay tree, *Eugenia acris*, citronella oil, methyl-eugenol and Mohihaua, an evergreen vine.

The males of *Dacus zonatus* Saund. (pest of peach, mango and citrus, etc.) are attracted to citronella, methyl-eugenol, inflorescence of Australian cycad and *Colocassia antiquorum*.

The females of *Dacus diversus* Coq. (pest of guava, mango and gourd, etc.) are attracted to the smell of sour sop (*Anona muricata*) and the males are strongly attracted to iso-eugenol and flowers of papaya, and both the males and females are attracted to clensel.

The males of *Dacus hageni* deM. (pest of gourd, pumpkin, sapota and tomato, etc.) are alone attracted to vanilla in amyl alcohol.

Bait-sprays. It is the considered opinion of the entomologists in all countries where fruit flies are a serious pest that the bait-spray offers one of the most effective methods of control especially in the pre-oviposition stage when the flies require plenty of water to drink and are easily attracted to any solution of syrup. This habit of the flies has been taken advantage of to poison and destroy them. A few branches and foliage in each tree in an orchard are swiftly sprayed so that the spray does not drizzle down but is retained on the leaves as droplets. The various insecticides employed are lead arsenate, paris green, potassium arsenate, sodium arsenate, copper carbonate, sodium fluosilicate and tartar emetic, etc. The insecticides are dissolved in a syrup of cane sugar.

Allman (1942) experimented with sodium fluosilicate and tartar emetic for the control of Queensland fruit fly, *Dacus tryoni* Frog. He found that (*a*) tartar emetic was more effective than sodium fluosilicate as it was not a repellent and caused less foliage injury, (*b*) sodium fluosilicate at a strength more than 1 oz. in four gallons of water acted as a repellent, and (*c*) that sugar was found better than molasses as a medium, as the latter was found not only to be distasteful but also caused considerable foliage injury. It is for reasons stated above that conflicting results have been obtained in the assessment of the success or failure of the bait-spray method of insect control. The effective formula worked out by him was poison 1 oz., sugar $2\frac{1}{2}$ lb., water 4 gallons. According to Steiner (1954) a poisoned

bait-spray containing malathion and hydrolysed or partially hydrolysed protein will give good control of the oriental fruit fly for one to three weeks. The fruit fly is attracted to the deposits by the protein material, which contains nutrients essential for their sexual development, and quickly ingest enough to kill it. The contact action of the deposits and contamination of natural food sources also contribute to fly mortality. The formula recommended for one acre is:

Ingredient	Concentrated spray	Dilute spray
Water	3 to 40 gallons	40 to 150 gallons
Yeast protein ..	1 lb.	1 lb.
Malathion, 25 per cent wettable powder ..	2 lb.	3 lb.

The protein should first be dissolved in water and thereafter malathion is added. Spraying should be done on the same day the bait is prepared. Protein bait-sprays are effective and not very costly. One application about the time the flies become active in summer might be highly effective and the flies at this time are probably with no food response.

BIOLOGICAL METHODS

The method of control of insect pests by means of their parasites or predators has made much progress within recent years. Hitherto spectacular success in the biological control of insect pests has been achieved only in those cases where the increase in the pest population was due to the absence of their natural enemies. In the words of Munro: 'If the increase of a noxious insect is the result of the absence or paucity of insects parasitic on it the logic of the method is unassailable, and it is noteworthy that where these conditions hold the success of parasite control is assured.' Let us now discuss what the position is in the case of the parasites of the fruit fly in India. Several species of fruit flies are attacked by two or three species of hymenopterous parasites belonging to the family Braconidae. It is, therefore, not advisable to introduce and establish parasites to control the species of flies that are already attacked by indigenous parasites; for it will result in needless competition and may even wipe out the little good that they are doing at the moment. Fullaway (1919) introduced *Opius fletcheri* Silv. from India to Hawaii for the control of *D. cucurbitae*, but this parasite did not reduce the pest to an

appreciable extent. Willard and Bissell (1926) achieved a measure of success in the control of the Mediterranean fruit fly, *Ceratitis capitata*, by the introduction and establishment of the eulophid parasite, *Tetrastichus giffardianus* Silv., from Africa and *Opius* (*Diachasma*) *tryoni* Cam. from Australia.

Hutson (1938) reported that *Spalangia* sp. (Pteromalidae), a pupal parasite of *D. dorsalis* introduced from Malaya, had successfully been established in Ceylon. *Opius oophilus* resulted in about a 95 per cent reduction in the *D. dorsalis* population in Hawaii. The absence of a major epidemic of fruit flies in India clearly shows that the parasites in association with several other factors are keeping the pest under check to a considerable extent. The survey of parasites of fruit flies has attracted considerable attention of the foreign entomologists with a view to introducing them in their countries where the fruit flies cause severe damage. Within the period of past 50 years, several foreign missions, viz. Compere (1907), Silvestri (1909), Fullaway (1915), Gurney (1935), and Bianchi Beevor and Lawrence (1950),* visited India to investigate the parasites of fruit flies. A brief and passing survey of the different species of the parasites of fruit flies that occur in India and the percentage of natural parasitism that occurs in nature are given below:

***Opius fletcheri* Silvestri** (Hymenoptera: Braconidae). As mentioned earlier the introduction and establishment of this parasite in Hawaii has met with partial success only. It is a pupal parasite (Plate III, fig. 8) of *D. cucurbitae* and the maggots of the flies are attacked when they are full-fed and make their exit from the fruit for pupation. The parasitic grubs complete their development within the pupae of the melon fly. In India, the effect of the parasite is observed late in August by which time a good deal of damage has been done. The maximum parasitization recorded is 20 per cent in the months of September-October. The parasite is distributed throughout India.

***Opius compensans* Silvestri.** It is found parasitizing 10–12 per cent puparia of *D. ciliatus* and *D. cucurbitae* in October and beginning of November. It also parasitizes the pupae of *D. dorsalis* in small numbers.

* The different years given in parentheses against authors do not refer to references but to the year of the visit by the scientist concerned.

***Opius persulcatus* Silvestri.** Gurney (1936) made an attempt to collect the parasites of fruit flies in India with a view to introducing and establishing them in his country for the control of Queensland fruit fly, *D. tryoni* Frog., in New South Wales. The species of fruit flies from which these parasites were reared was *D. dorsalis* and collections were mainly made from Bangalore (Mysore), and Coimbatore and Coonoor (Madras). The parasite, however, did not establish itself in New South Wales. It is a pupal parasite and the percentage parasitism recorded by Gurney was about 4 per cent. Gurney sent a few parasites to Fiji where they produced successful results. From Fiji consignments of parasites were sent to Cook, Western Samoa and Hawaii. Recently, this parasite has been introduced from the Philippines and Malaya into Hawaii for the control of *D. dorsalis*. The parasite has been reared from the pest but does not seem to have established well. According to Puttarudriah and Usman (1954), this parasite and *O. oophilus* together rank in importance next to *S. indicum* and among the parasite population their population is about 23 per cent in Mysore. This species also parasitizes *D. latifrons*.

***Opius oophilus* Fullaway.** This species occurs as a larval parasite of *D. dorsalis*. Though the parasitization of the fly in India is known to be less than 5 per cent, in Hawaii as mentioned before, it has proved to be an important parasite, parasitizing as high as 95 per cent of *D. dorsalis*. Further research might prove this parasite to be of equal value in this country as well. The species also parasitizes *D. latifrons*.

***Opius incisus* Silvestri.** This species of parasite was also reared by Gurney from the pupae of the above species of fruit fly. This parasite has been reared by Cherian and Sundaram (1941) from a collection of pupae from which hatched both *D. cucurbitae* and *D. ciliatus*. The species has also been recorded from Bangalore and South Coorg. The parasitization by this species hardly exceeds 1 per cent.

***Opius manii*.** This species parasitizes the pupae of *D. dorsalis* in Mysore.

***Opius longicaudatus* (Ashmead).** This parasite has been recorded from *Dacus* sp. in Bangalore.

***Opius* (= *Austroopius*) sp.** This species has been recorded as a pupal parasite of *D. zonatus* in Mysore.

***Opius* sp.** The authors have recently bred a Braconid parasite from the pupae of mango fruit fly, *D. dorsalis*, at Delhi (Plate I, fig. 7).

***Opius* (*Biosteres*) *carpomyiae* Silvestri.** Khare (1923) recorded it as a parasite of the fruit fly, *Carpomyia vesuviana*, in Nagpur. The parasite is found in the beginning of the season (October and November) along with *Bracon fletcheri* Silv. but has been recorded to be very active late in the season (March-April). The grubs pupate in the puparia of the flies. The maggots, when they bring their posterior ends near the minute holes on the surface of the fruit for respiration, are thrust with the egg of the female parasite. The same author has also recorded *Bracon fletcheri* parasitizing *Carpomyia vesuviana* larvae.

***Bracon fletcheri* Silvestri.** This parasite parasitizes the maggots of the *ber* fruit fly and is commonly found in the beginning of the season and decreases in numbers towards the end of the season in Nagpur. The grub when full-fed comes out of the maggot and pupates outside in the pulp of the fruits. The adult parasite comes out through the exit hole cut by the maggots and leaves the fruit for pupation. The way the parasite tries to parasitize the maggots within the fruit is similar to that of the preceding species. Both the maggots and the parasites have to take their own chances, the latter in attacking and the former in escaping. It is not yet known how it carries over every year through summer in the absence of its host. In spite of the presence of the two parasites in good numbers, the damage of the fruit fly is fairly severe. Recently, we have bred one Braconid and one Eulophid from the larvae and a Braconid from the pupae of *Carpomyia vesuviana* at Delhi. These have been identified to be *Bracon* sp., *Opius* sp. and *Omphale* sp. (Plate V, fig. 10, 11 and 12 respectively).

***Syntomosphyrum indicum* Silvestri (Eulophidae).** This parasite was first collected by Compere in 1907 in Bangalore, India. The species of fruit fly from which it was recorded was *D. dorsalis*. This parasite was also recorded by Gurney (1936) from Coimbatore, Coonoor and Bangalore in India. It was introduced by Compere in Australia and New South Wales, by Lounsbury in Cape and by Silvestri in Italy to check the damage caused by the Mediterranean fruit fly and the Queensland fruit fly. The parasite, however, did not establish itself in any of these countries. Though this parasite has been recorded in India we know very little about its biology and the per cent of parasitization

it brings about. It is one of the most important parasites of fruit flies and, therefore, further study of this parasite is greatly needed. According to Puttarudriah and Usman, 65·5 per cent of the total parasite population consists of this species in Mysore. Other parasites recorded on *Dacini* in India parasitizing the fruit flies in a minor form are given below:

Parasites		Hosts on which Recorded
Spalangia philippinensis Fullaway	(Spalangiidae)	*D. ciliatus*, *D. cucurbitae* and *D. dorsalis*
S. afra Silvestri	Do.	Do.
S. stomyoxysine Girault	Do.	Do.
S. grotiusi Girault	Do.	Do.
Spalangia sp.	Do.	*D. latifrons*
Dirhinus sp.	(Chalcididae)	*D. ciliatus* and *D. correctus*
Dirhinus giffardi Silvestri	Do.	*D. cucurbitae*, *D. dorsalis* and *D. latifrons*
D. luzonensis Rohwer	Do.	*D. ciliatus*, *D. cucurbitae*, *D. dorsalis* and *D. latifrons*
Pachycrepoideus dubius Ashmead	(Pteromalidae)	*D. ciliatus*, *D. cucurbitae* and *D. dorsalis*
Galesus sp.	(Diapriidae)	*D. ciliatus* and *D. dorsalis*
Trichopria sp.	Do.	*D. dorsalis*
Trybliographa daci Weld.	(Cynipidae)	Do.
Pseudeucoila sp.	Do.	Do.
Cothonaspis sp.	Do.	Do.

Tropideucoila sp. (Cynipidae) and *Ormyrus* sp. (Torymidae) are the two hymenopterous parasites recorded on the maggots of the safflower fruit fly (*Acanthiophilus helianthi*). Parasitization from both these species is of great economic importance, as the parasites

exert an effective check on the multiplication of the pest. The parasitization is only 5 per cent in March but rises up to 40 per cent in May. In association with *Ormyrus* sp. are found *Stenomalus muscarum* L. (Pteromalidae) and *Eurytoma* sp., but the precise rôle they play could not be determined by Pruthi and Bhatia (1940) who as already stated studied the biology of the safflower fruit fly.

Predators. The only predator recorded is *Chrysopa virgestes* which feeds on the maggots of *Acanthiophilus helianthi*. Poultry has so often been recommended as a means of control but it may be stated here that it does not help much because of the presence of crickets, grasshoppers, etc., which are readily eaten by the fowls and the overgrowing grass in which the infested fruit lies.

LEGISLATIVE OR QUARANTINE MEASURES

Timely quarantine measures against some of the serious insect pests have been found not only one of the chief methods of insect control but also perhaps the surest way to prevent the entry of injurious insects and the drain in the National Exchequer. In addition to the fruit flies mentioned above there are some other important species of fruit flies listed below. Entry of any of these destructive fruit flies into our country would be a catastrophe and would almost create a crisis in our fruit-growing industry. It is, therefore, imperative that all necessary quarantine measures be taken up at an early date in the wide interest of the fruit industry of the country.

Some of the more important genera of fruit flies and their origin are as follows:

Genus	Origin	Most important species
1. *Ceratitis*	Equatorial Africa	(*a*) Mediterranean fruit fly (*C. capitata* W.) (*b*) Natal fruit fly [*C.* (*Pterandrus*) *rosae* K.]
2. *Dacus*	Equatorial Africa, Pacific and Oriental Regions	(*a*) Olive fly (*Dacus oleae* Rossi) (*b*) Queensland fruit fly (*D. tryoni* Frog.) (*c*) Japanese (also Chinese) Orange fruit fly (*D. tsuneonis* Miyake)
3. *Anastrepha*	Tropical America	(*a*) Mexican fruit fly (*A. ludens* Loew) (*b*) West Indian fruit fly (*A. mombinpraeoptans* Sein)
4. *Rhagoletis*	North America	(*a*) Apple maggot (*R. pomonella* Walsh) (*b*) Cherry fruit flies (*R. cingulata* Loew and *R. fausta* O. S.) (*c*) Walnut husk fly (*R. completa* Cress)

Our country is exposed to the danger of introduction of the above species and, therefore, all fruits and vegetables and plants serving as hosts of the flies or portions of plants used as packing for fruits and vegetables should be totally prohibited. The fruits and vegetables may be allowed to enter from the country of origin provided the consignment is accompanied by a certificate from the Government entomologist of that country of origin that the exported fruits are not the carriers of fruit fly pest or the products have been shipped from the country free from fruit fly infestation. Also that the boxes containing fruits were subjected to live steam in a closed container for a prescribed period for each species of the fruit fly and that the boxes are free from leaves and twigs of the plants likely to carry the infestation of the fruit flies.

USE OF ATOMIC ENERGY FOR THE CONTROL OF FRUIT FLIES

Within recent years advances in our knowledge of nuclear physics have opened an entirely new vista for enduring research work in biological problems. In the field of applied entomology the use of radio-active isotopes has met with spectacular success in the control and the eradication of the screw-worm, *Callitroga hominivorax* Eqrl., a serious pest of cattle in Curaçao Island. Some of the prerequisite conditions to achieve this success were there in the case of the screw-worm like (i) a small localized area to deal with, (ii) the habit of the female to mate only once, (iii) economical breeding of the pest in the laboratory, and (iv) that the stage of the pest that is released is not the damaging stage of the pest concerned.

In the case of fruit flies also experiments are in progress in Hawaii whether this method could be applied in controlling or eradicating this pest. Here, however, some of the main prerequisites are not present. Fruit fly infestation is over a much wider and larger area than the screw-worm and the female mates more than once. Till now the preliminary experiments carried out at Hawaii have not yielded positive results. The whole problem bristles with difficulties. We have to irradiate millions of pupae and release sterile adult fruit flies in areas of severe infestation. Even this may not yield satisfactory results as the fruit flies already present in the area may migrate on account of this very large influx of irradiated population. This method, however, opens up new fields for experimental research work both in the laboratory and in the field.

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